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THE NOVEMBER SCIENTIFIC MONTHLY

EDITED BY J. MCKEEN CATTELL

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RELATION OF EROSION TO VEGETATIVE CHANGES. HUGH HAMMOND BENNETT 385
SOME PROBLEMS OF STREET AND HIGHWAY. PROFESSOR KNIGHT DUNLAP 416
PURE AIR FOR OUR CITIES. PROFESSOR D. B. KEYES 427
THE ORIGIN AND DESTINY OF ENERGY. DR. MASON E. HUFFORD 431
RECENT TRENDS IN GEOGRAPHY. PROFESSOR STEPHEN SARGENT VISHER 439
PROHIBITION AND THE STRAW BALLOT. PROFESSOR H. H. MITCHELL 443
SCIENCE SERVICE RADIO TALKS:
ELECTRICITY, THE MODERN HANDMAID OF CHEMISTRY. DR. COLIN G. FINK 449
SCIENCE IN FOOD PRODUCTION. DR. RAYMOND A. PEARSON 451
THE MEDICAL CARE OF ANIMALS IN THE ZOO. DR. W. REID BLAIR 454
DAY-DREAMS. DR. EDWIN G. FLEMMING 458
CHANGING FAMILY SITUATIONS IN A SMALL COMMUNITY. DR. EARL H. BELL 462
ACTION OF A RUNNING HORSE. DR. EDWIN H. HALL 466
THE PROGRESS OF SCIENCE:
The International Congresses of Physiology and Psychology; The Ithaca Meeting of the American Psychological Association; Cosmic Rays at Forty Billion Volts; Preliminary Results from the Total Eclipse; Earthquake and Hurricane; The Physiology of Respiration 470

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THE SCIENTIFIC MONTHLY

NOVEMBER, 1932

RELATION OF EROSION TO VEGETATIVE CHANGES

By HUGH HAMMOND BENNETT

BUREAU OF CHEMISTRY AND SOILS, U. S. DEPARTMENT OF AGRICULTURE

EXCESSIVE erosion has so profoundly changed the soil over vast agricultural areas that it is hard to understand why, until recently, systematic studies pertaining to the process and its attendant evils have been almost completely excluded from our research programs and economic theses. Undoubtedly, the neglect of this problem of continuing soil wastage and depreciation, which more than any other process alters the physical characteristics and crop-producing capacity, or plant responsiveness, of sloping land, has had closest causal relation to the prevalent conception that erosion belongs to the natural order of terrestrial dynamics—that it represents an uncontrollable agency which, through prolonged ages, has fashioned countless valleys over the world, dug prodigious canyons and otherwise accomplished an unmeasurable amount of work, part of which (that is, of normal erosion) has been beneficial to man. Geologists have given due consideration to the sharp edge of this prodigious implement of land carving, but others generally have not. There has been too much of the point of view that erosion is a necessary evil that must be borne with.

To a considerable degree, this conception is based upon substantial foundation, in so far, and only in so far, as it pertains to normal erosion. The exceedingly slow removal of surface soil, proceeding under normal conditions of ground stabilization, such as is established and approximately maintained through the instrumentalities of vegetative cover, the relatively high absorptive capacity that goes with normally developed soil porosity (an element of soil structure) and the restraining influence of gentle slope or of angle of repose. Vegetation and soil structure, separately and collectively, exert a tremendous opposing force to transportation of soil material by running water, slowing down surface removal to a point where equilibrium between rate of planation and soil building from the parent materials beneath is almost, but not quite, established. Had these more or less counterbalancing natural processes attained equilibrium some eons ago, vastly more poorly drained land of impervious claypan and hardpan characteristics unquestionably would have developed throughout the world, as well as much more of severely leached and exceedingly infertile land, such as the laterites of the humid tropics.

ABNORMAL EROSION

This paper is not primarily concerned with the effects of normal or natural erosion, except as a basis for comparison. It pertains to changed physical, chemi-

FIG. 1. EROSION, FOLLOWING CULTIVATION

HAS CONVERTED THIS LARGE AREA (SOUTHERN VIRGINIA) OF FORMERLY SMOOTH-SURFACED LAND INTO A CONDITION OF ROUGH, BROKEN LAND, WITH MORE THAN 50 PER CENT. OF THE AREA REDUCED TO ALMOST COMPLETE STERILITY, SUPPORTING ONLY A SCATTERING GROWTH OF WEEDS AND STUNTED BLACKBERRIES, AND AN OCCASIONAL PINE OR CEDAR.

eal and biologic conditions resulting from abnormal erosion, the accelerated soil washing following man's activities, his free use of axe and plow and the overcrowding of live stock upon sloping ranges. Destruction of vegetation and disruption of the natural ground structure (the structural efficiency of the soil, as pertaining to its capacity for disposing of rainfall by absorption and percolation) have caused the speeding up of erosion far beyond common belief, indeed, almost beyond the limits of comprehension.

The various phases of land wastage resulting from these disturbances of virgin soil conditions do not, then, represent a normal outgrowth of nature's operations, but, rather, the artificial development of tremendously different physical characteristics and ecologic conditions, as compared with the original soil. In their causal relationships to vegetative changes, these man-induced conditions of the soil, these results of excessive erosion, have specifically received very little attention by botanists, and much too little by ecologists, geographers, crop specialists and farmers. The fact that the earth's mightiest chasm, the Grand Canyon of the Colorado, was in the making before man arrived with his implements of destruction is no contradiction of what is averred here, for the simple reason that nothing is known of the conditions existing at that remote period. Climatic records are lacking; there is no knowledge as to the effects of possible overpopulation of herbivorous animals upon those primordial watersheds.

Removal of Humus-charged Topsoil

The most productive part of the humus-charged, sponge-like, absorptive topsoil, with its host of beneficial microorganisms and relatively high content of readily available plant nutrients, is attacked first by this accelerated erosion. In place of the original surface layer, characterized by optimum conditions (for any definite type of soil) of mellow-

ness, granulation and openness or porosity, such as favor conservation of moisture and ready penetration by fibrous plant roots seeking moisture and food. Erosion-exposed subsoil is substituted through the simple process of washing off the comparatively shallow topsoil. This less productive material is of much lower organic-matter content,[1] usually is relatively higher in clay and so generally stiffer (more dense and sticky), is less absorptive of rainfall and is much more subject to running together, baking (compacting), cracking and dangerous depletion of available moisture in time of drought. Aside from the vast impairment of crop and grazing lands in the United States (and many other countries) and essential destruction of numerous areas (in the sense of economic crop production), the process has markedly altered the details of topography[2] in countless places and has entirely changed the type of vegetation that originally characterized millions of acres of farm and grazing land (Fig. 1).

This paper undertakes to emphasize these profound erosion-produced alterations in the vegetative aspects of the land. The subject can not be covered in detail at this time; its importance as a geographic, edaphic and economic problem only can be stressed here. With the pertinent quantitative data now being accumulated at the various regional soil erosion experiment stations, together with the results of soil surveys and erosion surveys,[3] the time seems appropriate for undertaking to arouse greater interest in the meaning of these newly created plant environments. At the moment, the changes and their economic significance will be defined by pointing to various representative examples. It scarcely seems necessary to observe, after what has been said, that the subject relates to destructive soil processes, as opposed to the ordinary conception of soil-building processes. Nevertheless, it is important to remember that these new soil conditions, so tremendously affecting plant adaptability and growth, are not only already wide-spread throughout the United States but are being rapidly extended, under the methods of agricultural practice in vogue, over a large proporton of the cultivated land of the nation, 75 per cent. of which, at least, is sloping and subject in varying degrees to wasteful erosion.

[1] H. H. Bennett, "Cultural Changes in Soils from the Standpoint of Erosion," *Journal Am. Soc. of Agronomy*, 23: No. 6, June, 1931.

[2] Numerous slopes that formerly were smooth and regular are now characteristically rough or broken, by reason of gullies that extend to depths of 10, 20, 40, 50, 75 and even 100 feet (see "Soil Survey of Stewart County, Georgia," U. S. Dept. of Agric., Field Operations (Report 15), Bur. of Soils, 1913, pp. 545-606).

[3] H. H. Bennett, "The National Program of Soil and Water Conservation," *Journal Am. Soc. of Agronomy*, 23: No. 5, May, 1931.

Relation of Soil to Vegetation

The character of the topsoil as it exists in the virgin state, from place to place, strongly influences the type of vegetation growing on it, due to the varying adaptative factors involved. These edaphic characteristics pertain not only to native and introduced plant species, but to ordinary farm crops as well. For example, it is very well known in Cuba that certain varieties of sugar-cane which grow splendidly on moist alluvial soils give exceedingly poor yields on droughty uplands; whereas, other varieties, giving but indifferent yields on precisely the same alluvial soils, get along nicely under the adverse moisture environment of the uplands. This profound effect of soil character on plant growth is strikingly revealed in many of the well-drained cane fields of the Caribbean Islands. On certain areas the plants remain green and continue to grow throughout the dry season, normally of five to six months' duration; while those of the same variety on adjacent areas

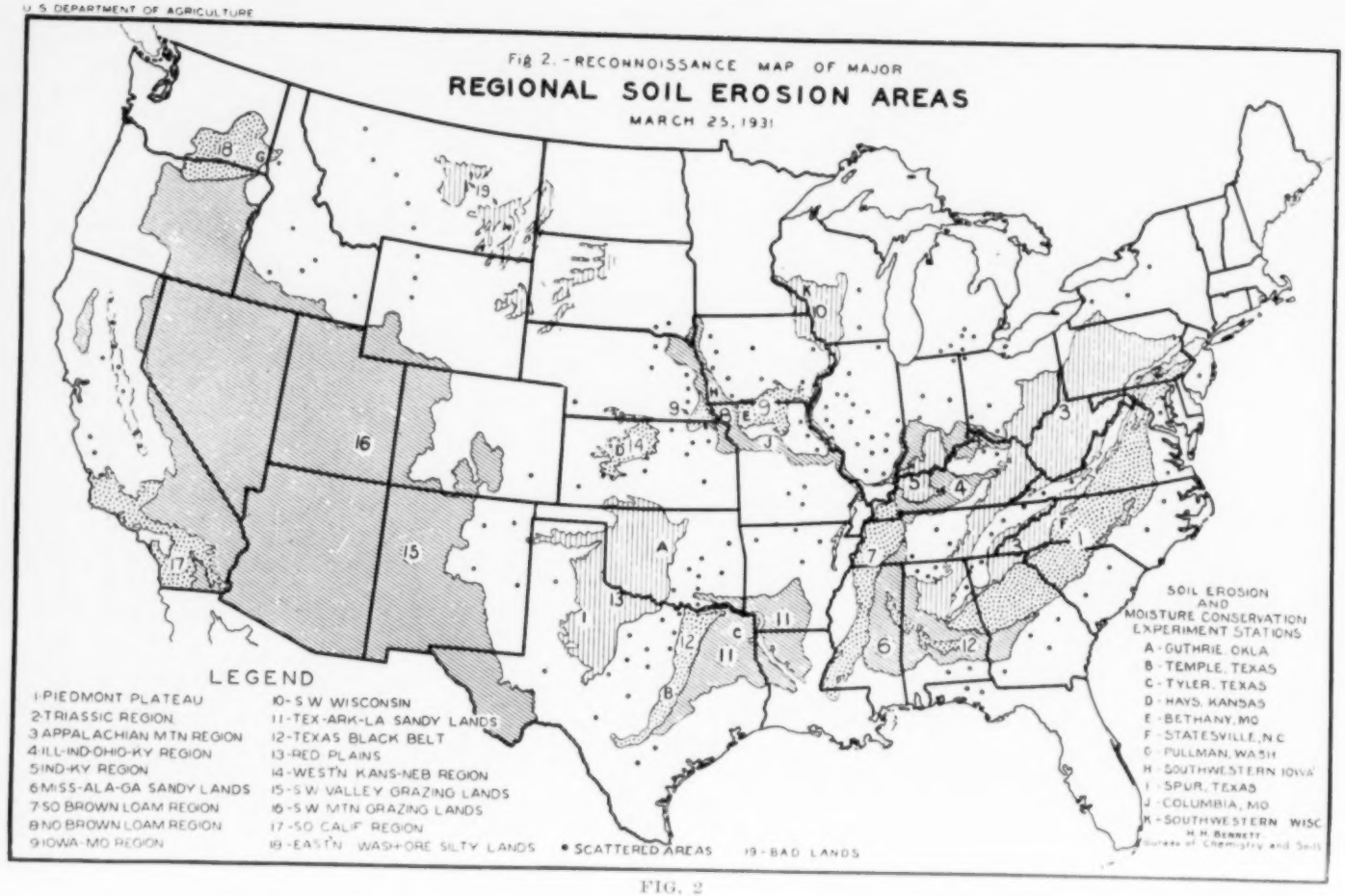
U. S. DEPARTMENT OF AGRICULTURE
Fig 2.-RECONNOISSANCE MAP OF MAJOR
REGIONAL SOIL EROSION AREAS
MARCH 25, 1931
LEGEND
1-PIEDMONT PLATEAU
2-TRIASSIC REGION
3-APPALACHIAN MTN REGION
4-ILL-IND-OHIO-KY REGION
5-IND-KY REGION
6-MISS-ALA-GA SANDY LANDS
7-SO BROWN LOAM REGION
8-NO BROWN LOAM REGION
9-IOWA-MO REGION
10-S W WISCONSIN
11-TEX-ARK-LA SANDY LANDS
12-TEXAS BLACK BELT
13-RED PLAINS
14-WEST'N KANS-NEB REGION
15-S W VALLEY GRAZING LANDS
16-S W MTN GRAZING LANDS
17-SO CALIF REGION
18-EAST'N WASH-ORE SILTY LANDS
• SCATTERED AREAS
19-BAD LANDS
SOIL EROSION AND MOISTURE CONSERVATION EXPERIMENT STATIONS
A-GUTHRIE, OKLA
B-TEMPLE, TEXAS
C-TYLER, TEXAS
D-HAYS, KANSAS
E-BETHANY, MO
F-STATESVILLE, N C
G-PULLMAN, WASH
H-SOUTHWESTERN IOWA
I-SPUR, TEXAS
J-COLUMBIA, MO
K-SOUTHWESTERN WISC
H. H. BENNETT,
Bureau of Chemistry and Soils

FIG. 2

of markedly different soil parch, stop growing or die. Examination of these areas invariably reveals that the green fields are on mellow soil, usually rich in lime and humus, such as retain favorable supplies of moisture throughout the dry period; whereas, the fields of dormant or dead plants are invariably restricted to soils which, though having the same slope and receiving the same rainfall and cultural treatment, lose their available moisture soon after cessation of the rains. Here, soil character is sufficiently potent in its relation to growth of sugar-cane (and a number of other crops) to maintain the equivalent of a humid climate within a temporary desert area.[4]

Exactly the same behavior may be witnessed in the corn, wheat and cotton fields of America, especially where severely washed, soil-stripped land is associated with land still retaining its topsoil, or a considerable part of it. Almost invariably crops growing on erosion-exposed subsoil suffer much more in dry weather than those growing on uneroded soil. This is particularly true of the more succulent plants, as corn, vegetables and melons. Unquestionably the difference is the result of (a) deficiency of effective moisture (moisture available to plants) and (b) deficiency of readily available plant nutrients in the areas of exposed raw (unweathered) clay.

If soils differ in their virgin condition sufficiently to affect plant growth to the extent of counterbalancing an environmental factor equivalent to the difference between a humid climate and a desert climate, such as can be seen in the sugar-cane fields of Cuba every year, even on freshly cleared forest land, what, then, is to be expected when the original differences between two such soils are still further increased by the complete removal of that part of one of them, the humus-charged topsoil, which of all the soil layers from the surface deep into the subsoil most nearly matches the corresponding layer of the other type, and which, of all the layers, normally has the greatest capacity for manufacturing available plant food? In other words, soils whose responsiveness to plant growth varies widely in the virgin condition frequently show even greater variation, following removal of the surface layer from one of them. As between two inherently different soils, the normal tendency of erosion is not merely to minimize or eliminate the soil-equalizing effect of the organic matter and the population of micro-organisms contained chiefly in the uneroded topsoil by removing this layer; but it is to impoverish land, also, by bringing quickly to the surface unweathered, unconditioned (in relation to normal-soil plant growth) material entirely unlike and inferior to that which has been bodily swept away. If it can be called soil, then this freshly exposed material obviously is of a very different type, one constituting an entirely changed plant environment.

The Oklahoma Erosion Survey

In 1930 an erosion survey[5] of Oklahoma was completed which showed that of approximately 16,000,000 acres in cultivation in the state, 13,000,000 were subject to excessive washing, nearly 6,000,000 acres having reached the stage of gullying, with 374,000 acres, still included in fields, so badly gullied that good farm machinery could not cross the devastated areas. The survey revealed further that during the "last three or four years" 1,359,000 acres of

[4] H. H. Bennett, "Some New Cuban Soils," a supplement to the "Soils of Cuba," Scientific Contribution No. 22, Tropical Plant Research Foundation, Yonkers, N. Y., 1932.

[5] N. E. Winters, "The Oklahoma Soil Erosion Survey," Report of the Proceedings of the Second Southwest Soil and Water Conservation Conference, Circular No. 79, Oklahoma Agricultural and Mechanical College, pp. 9–11, 1931.

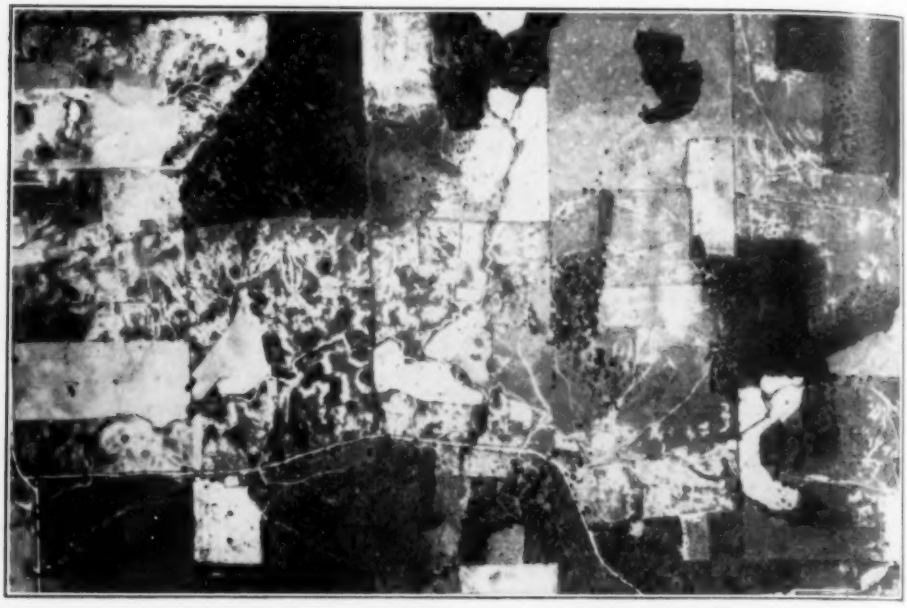

FIG. 3. AIR PHOTOGRAPH OF ABOUT 840 ACRES, SOUTHERN INDIANA

TWENTY-FIVE PER CENT. TIMBERED (DARK CLUMPY AREAS), WITH ONE HALF REPRESENTING RATHER SCRUBBY SECOND GROWTH ON LAND WHICH WAS ABANDONED BECAUSE OF EROSION; 11 PER CENT. PLOWED IN 1930, THOUGH PARTLY ERODED (LIGHT-COLORED GEOMETRIC PATTERNS); 64 PER CENT. ABANDONED BECAUSE OF EROSION (A—LIGHT COLORED AREAS OF IRREGULAR OUTLINE, DEEPLY ERODED AND SUPPORTING LITTLE OR NO VEGETATION, AND B—GRAY AREAS REPRESENTING FIELDS ABANDONED, NOW COVERED LARGELY WITH BROOM SEDGE). TOTAL ABANDONMENT WITHIN THIS AREA OF FORMERLY HIGHLY PRODUCTIVE LIMESTONE SOIL (OF THE GENERAL CHARACTER OF FREDERICK SILT LOAM), BECAUSE OF IMPOVERISHMENT BY EROSION, AMOUNTS TO APPROXIMATELY 75 PER CENT. OF THE AREA. THIS CONDITION OBTAINS OVER A VERY LARGE AREA IN THE LIMESTONE REGIONS OF INDIANA, OHIO, KENTUCKY AND TENNESSEE. PHOTO FURNISHED BY PURDUE UNIVERSITY AGRICULTURAL EXPERIMENT STATION.

formerly tilled land had been abandoned because of erosion.

The vegetative changes from the original virgin post oak forest and "bluestem prairies" of many localities were found to have been so great over the rolling part of the state that this feature was helpfully employed as a soil-condition indicator in connection with the classification of certain types of idle eroded land. In the Red Plains region (Fig. 2)[6] the original valuable prairie vegetation on the very extensive type of farm land, the Vernon fine sandy loam,[7] composed chiefly of *Andropogons* (as little bluestem and big bluestem), together with some grama grasses, has been replaced on the erosion-exposed, droughty red clay subsoil by an essentially worthless sod composed of weeds and such inferior forage plants as the needlegrasses.

This sweeping vegetative change has

[6] There is much eroding land of scattered occurrence outside the major regions indicated on this general map.

[7] For description of the Vernon soils, see E. H. Smies, "Soil Survey of Canadian County, Oklahoma," U. S. Department of Agriculture, Field Operations of the Bureau of Soils, 1917.

accompanied an almost hopeless decline in the economic value of a tremendous area of farm land within the Red Plains of both Oklahoma and Texas.

Hardwoods Replaced by Persimmon and Sassafras

In the east Texas sandy lands region (Fig. 2), where numerous fields have been abandoned because of erosion, thickets of small persimmon trees are very common, especially on the red soils of the Kirvin group.[8] Almost without exception, examination of these sites shows that they consist of stiff red clay or a very thin covering of comparatively infertile grayish sandy loam over red clay. Remnants of the regional virgin hardwoods, including principally oaks and hickory, reveal that all these soils once had a covering of about 6 to 8 or 10 inches of light-brown to yellow fine sandy loam over red clay, the true topsoil or humus-charged layer averaging about 4 or 5 inches in depth. This surface soil has been partly or completely removed, and the lighter colored subsurface layer also, over thousands of acres. Following such denudation, persimmon trees and smilax have sprung up abundantly, along with broom sedge, poverty grass and a variety of worthless weeds. Wherever seed trees occur, there usually has been, also, a rather wide dispersal of pine.

In the rolling areas of the formerly

[8] For description of the Kirvin soils, see B. H. Hendrickson, R. E. Devereux and E. H. Templin, "Soil Survey of Nacogdoches County, Texas, U. S. Department of Agriculture, Field Operations of the Bureau of Chemistry and Soils, 1925.

FIG. 4. ABOUT 1,500 ACRES OF FORMERLY RICH LIMESTONE SOIL HAS BEEN ABANDONED IN THIS ONE LOCALITY (SOUTHERN INDIANA) BECAUSE OF EXCESSIVE EROSION, FROM ABOUT 4 TO 8 FEET OF SOIL AND SUBSOIL HAVING BEEN REMOVED, DOWN TO BEDROCK, IN NUMEROUS PLACES. THE ORIGINAL VEGETATION WAS A HEAVY HARDWOODS GROWTH; NOW MUCH OF THE LAND IS BARE, OR ESSENTIALLY SO, AND THE REMAINDER IS COVERED CHIEFLY WITH BROOM SEDGE, POVERTY (NEEDLE) GRASS AND WEEDS, MUCH OF WHICH IS DWARFED AND OF VERY SPARSE DISTRIBUTION. PERSIMMON TREES HAVE COME IN SCATTERINGLY. THIS IS THE TYPE OF SEVERELY ERODED COUNTRY SHOWN IN AIR PHOTOGRAPH, FIG. 3.

rich limestone soils of the Highland Rim section of southern Kentucky, the thick clumps of sassafras almost universally present in abandoned fields usually mean simply one thing: That the former covering of humus-charged, mellow silt loam has been washed off down to much stiffer clay material that dries out and hardens more quickly. The vegetation coming in on the abandoned fields is entirely different from that of the hardwoods originally covering these productive uplands, and it is not known what length of time would be required for reestablishment of anything like the virgin stand of timber.

In 1930 a soil survey was completed of Washington County, Indiana, where the base map was prepared from air-photographs made during the very dry season of that year. Much land has been completely or part-time abandoned here because of excessive soil washing—something like 25 to 30 per cent. of the entire county as indicated by the air map and soil survey. The vegetation on the critically eroded areas is so unlike that where part of the original topsoil still remains, it was an easy matter to pick out the denuded areas on the photographic sheets. Abandoned fields which had washed down to clay were essentially bare of vegetation during the excessively dry period referred to, while those old fields which had lost all but a

FIG. 5. DEEPLY ERODED AREA OF FORMERLY CULTIVATED PIEDMONT SOIL

(CECIL SANDY LOAM) WHICH IS ESSENTIALLY STERILE. IT HAS A DECIDED ACID REACTION (pH 5.35), WHICH, HOWEVER, IS THE CONDITION OF THE FORMER OVERLYING MATERIAL, AS DETERMINED BY EXAMINATION OF THE VIRGIN PROFILE OF NEAR-BY AREAS (pH 4.87 AT SURFACE AND 5.05 AT 3½ FEET BENEATH), INDICATING IN THIS INSTANCE THAT IT IS NOT THE CONDITIONS WHICH ACCOMPANY ACIDITY BUT OTHER UNFAVORABLE CONDITIONS THAT CAUSE THE STERILITY OF THIS "RAW" CLAY. HERE SOME 3 FEET OR MORE OF SOIL AND UPPER SUBSOIL HAVE BEEN REMOVED. THE PINES IN THE MIDDLE GROUND ARE GROWING IN DEPRESSIONS WHERE MORE PRODUCTIVE EROSIONAL DÉBRIS HAS ACCUMULATED, WHILE THE HARDWOODS IN THE BACKGROUND ARE ON VIRGIN SOIL.

FIG. 6. PIEDMONT AREA

WHERE THE ORIGINAL GRANITE-DERIVED SOIL (CECIL SANDY CLAY LOAM) WAS FIRST CULTIVATED UNTIL THE SOIL WAS COMPLETELY REMOVED BY SHEET EROSION, AS WELL AS PART OF THE SUBSOIL, AND THEN ABANDONED. PINES VOLUNTARILY COVERED THE AREA, BUT FAILED TO COMPLETELY STOP THE WASHING, ESPECIALLY IN THE GULLIES. CONTINUING EROSION REMOVED THE MORE PRODUCTIVE PART OF THE SUBSOIL DOWN TO COMPARATIVELY UNPRODUCTIVE DEEP SUBSOIL, MUCH LIKE THAT IN FIG. 5; AND NOW THE PINES NOT ONLY ARE MAKING NO HEADWAY, BUT MANY OF THEM ARE DYING.

thin covering of the original silt loam supported principally broom sedge. These features are all plainly legible on the aerial map (Fig. 3).

Detailed studies of a number of the virgin profiles (vertical soil section) of the limestone soils of this southern Indiana county, which originally supported a splendid stand of oak, hickory, maple, elm, basswood, cherry, buckeye and walnut, show that the immediate topsoil of the most extensive types is considerably more alkaline than the sublayers. The deep-lying substratum material, on the other hand, is more alkaline than either the topsoil or the intermediate layers. Obviously, the plant roots, bringing up soluble basic constituents from the alkaline substratum and storing them in the leaves of forest trees, have in this indirect way transferred such alkaline material to the surface soil, to make it more productive than the layers immediately beneath. It was found that the immediate topsoil, *i.e.*, the mineral soil beneath the forest-litter, of the Frederick and Canton silt loam soils, is nearly neutral, while the various layers of the subsoil proper are of acid reaction, some of them very acid. Also, the material of the substratum was found to be acid in the upper part and decidedly non-acid (alkaline) beneath, where freshly decomposed limestone material is present.[9] It was shown, too, that the humus cover, to depths of about

[9] Data from unpublished manuscript covering the report on the survey of Washington County, Indiana, by J. T. Miller, U. S. Department of Agriculture, Bureau of Chemistry and Soils, and E. Waggoner, Purdue University.

FIG. 7. ABANDONED FORMER FIELDS, WEST-CENTRAL NEW JERSEY FROM WHICH MORE THAN 4 FEET OF SOIL AND SUBSOIL HAVE BEEN WASHED. THIS AREA (IN WHICH PHOTOS SHOWN IN FIGS. 9 AND 11 WERE MADE) IS NOW EXCEEDINGLY POOR, ROUGHLY GULLIED LAND, ABOUT 40 PER CENT. BEING BARE AND THE REMAINDER COVERED CHIEFLY WITH POVERTY GRASS.

1, 1½ or 2 inches, ranges from approximately neutral to alkaline in every instance.

These characteristics of the successive layers through the vertical soil section afford a clear picture of what happens to the productivity of such lands under those unwise farm practices which permit the topsoil to wash off. Actually, bluegrass growing abundantly on the comparatively "sweet" (alkaline) virgin soil has been displaced, on the exposed acid, droughty subsoil, by persimmon, broom sedge and worthless weeds, with numerous areas supporting no vegetation or only scattered weeds and grass of dwarfed growth (Fig. 4).

Effect of Erosion in the Southern Appalachians

While making a reconnaissance survey of erosion conditions in the southern Appalachian region, during 1931, it was observed that the broad-leaved forests have been practically all cleared from the slopes of numerous valleys within the Blue Ridge Mountains (where the principal soils are derived from granitic rocks and micaceous schists) for a distance ranging from about a half to three quarters of a mile or more up the slopes rising from the alluvial plains bordering the streams. From about one third to more than three fourths of these formerly cultivated areas have been abandoned because of the severity of erosion. The character of the vegetation coming in after the stripping off of the surface layer (as well as the subsoil in many instances) contrasts violently with the former heavy forests of oak, chestnut, hickory, maple, sourwood, cucumber tree, tulip-poplar, rhododendron, laurel, azalea, etc. Most of the abandoned land

is covered with pine, although some areas support dense stands of tulip-poplar.

Out in the Piedmont country, east of the Blue Ridge, where erosion has devastated numerous areas, a variety of vegetative changes have taken place on the extensive Cecil soils (granite-derived soils having brittle red clay subsoils), following the gradual washing off first of the topsoil and then of the subsoil, on down into the lighter colored substratum, consisting of intermingled clay and particles of disintegrated rock. The exposed subsoil (*i.e.*, the upper subsoil) is farmed for a while with the aid of fertilizers, although all crops suffer on it during droughts, corn frequently failing completely at the same time when fairly good crops are produced on the associated less severely washed soils of the same original type. Continuing erosion lowers the surface of the ground until finally the poor, intractable deep-subsoil material is reached, at which stage the land is essentially worthless for crop production. Even the pines that grew well on the upper subsoil now fail to make much headway. They are characteristically stunted; some of them actually die as the result of continuing washing (Figs. 5 and 6).

Many of these deeply eroded areas are bare of vegetation, save for an occasional dwarfed blackberry or smilax. The broom sedge, blackberries and weeds that flourished on the upper subsoil of the fields that were thrown out of cultivation immediately following the stripping off of the surface soil usually grow

FIG. 8. SLOPE ABOVE FIGS. 7, 9 AND 11, NEVER CULTIVATED

SUPPORTING HARDWOODS OF CHESTNUT, OAK, BEECH, MAPLE, DOGWOOD, ETC. THE SOIL BENEATH THE CARPET OF FOREST-MOLD CONSISTS OF BROWNISH, MELLOW LOAM ABOUT 8 INCHES DEEP OVERLYING LIGHT-REDDISH LOAM TO CLAY LOAM CONTAINING SOME ROUNDED GRAVEL (WASHINGTON LOAM). AT DEPTHS OF ABOUT 36 TO 40 INCHES, RED CLAY, SUCH AS THAT SHOWN IN FIGS. 7, 9 AND 11, IS REACHED. ALL THE MATERIAL OF THIS ORIGINAL COVERING OF LOAM HAS BEEN REMOVED FROM MOST OF THE FORMER FIELDS ON THE SLOPES BELOW, WITH THE EXCEPTION OF THE LARGER GRAVEL; AND THE VEGETATION ON THE ABANDONED, DEEPLY ERODED AREAS IS VASTLY DIFFERENT FROM THAT OF THE VIRGIN FORESTS, AS SHOWN HERE.

FIG. 9. NO VEGETATION ON DEEPLY ERODED RED SHALE SOIL (PENN CLAY)

WEST-CENTRAL NEW JERSEY. NOT LESS THAN 4 FEET OF SOIL AND SUBSOIL HAVE BEEN ERODED FROM THIS AREA (2.9 FT. × 4.4 FT.) SINCE IT WAS BROUGHT INTO CULTIVATION. THE AREA IS STILL ERODING.

FIG. 10. PATCHY ASSOCIATION OF BLACK PRAIRIE SOIL AND EROSION-EXPOSED WHITE SUBSTRATUM MATERIAL (CHALK), BLACK BELT OF TEXAS, NEAR TEMPLE. THE WHITE AREAS, FORMERLY COVERED WITH TWO FEET OR MORE OF BLACK TOPSOIL AND YELLOWISH SUBSOIL, ARE MUCH LESS PRODUCTIVE THAN WAS THE ORIGINAL SOIL.

stuntedly and sparsely, or not at all, on this essentially sterile material, representing the last stages of erosion before exposure of bedrock.

Lee has the following to say with respect to vegetation on the Cecil clay loam of Burke County, North Carolina,[10] an erosive soil (usually representing exposed subsoil of areas that formerly consisted of Cecil sandy loam and loam):

> Abandoned fields first grow up in broomsedge and brambles, followed the second year by sassafras, sumac bushes and yellow pine, and in a few years, except on badly eroded areas, there is a good stand of pine. Forested areas support a fair or good growth of white, red, black, post, scarlet and chestnut oaks, shortleaf or yellow pine, spruce, pitch and white pines, hickory, black gum, yellow poplar, dogwood and a few persimmon, locust sourwood, black walnut, white elm, sweet gum, red cedar and hemlock trees.

The following observations[11] relate to the far-reaching vegetative changes that have taken place over millions of acres throughout the southern Piedmont region, mainly on the Cecil soils:

> The original forest growth was quite different from the forests of the present time. On the highlands the oak, hickory, and chestnut were of large growth and stood far apart. There was no underbrush and the woods were carpeted with grass and the wild pea vine. Along the streams and in the valleys the distinctive growth was willow, beech, birch, black walnut, ash, poplar, and gum. The cane also flourished best here, although it often grew upon the higher ground. The cane growth was the standard by which the early settlers estimated the value of the land. If it grew only to the height of a man's head, the land was esteemed ordinary, while a growth of from 20 to 30 feet indicated the highest fertility.
>
> Not only the forests, but the cultivated fields as well, present a very different aspect now from what they did after the country was first opened up. It was then new and beautiful and as remarkable for the luxuriant richness of its landscape as it is now for the striking features of its rolling hills and long, narrow valleys. The original forest has disappeared almost entirely, and has been replaced by scrubby oaks, by underbrush, and by shortleaf pines of the abandoned fields. The chestnut and chestnut oaks have been dying out for the past sixty years, and the cane has likewise almost disappeared.

Second-growth pine in the Piedmont region usually means eroded land wherever found in essentially pure stands on sloping areas. Much of it grows where the original soil has completely disappeared. A rough picture of what has taken place can be formulated from conditions in Spartanburg County, South Carolina. In this one county alone 297,216 acres have been classed and mapped as clay loam and sandy clay loam.[12] Examination of the soil profile as found in remnants of the virgin stands of mixed hardwoods and shortleaf pine ("forest pine") shows the original soil to consist of some 4 to 8 inches of brownish or yellowish, mellow sandy loam and loam. This top layer is gone, or largely gone, from 297,000 acres of clay loam and sandy clay. These soils (classed as Cecil clay loam, sandy clay loam and gravelly sandy clay loam and as Louisa clay loam and sandy clay loam) are, in a sense, new soils, representing products of the excessive erosion which has taken place over the cultivated slopes.[13] Not only are they markedly different from the virgin soils tex-

[10] Soil Survey, Burke County, North Carolina.

[11] F. W. Taylor and Thomas D. Rice, "Soil Survey of the Abbeville Area, South Carolina," U. S. Department of Agriculture, Field Operations of the Bureau of Soils, 1902.

[12] W. J. Latimer, E. B. Deiter, S. O. Perkins, W. Edward Hearn and Cornelius Van Duyne, "Soil Survey of Spartanburg County, South Carolina," U. S. Department of Agriculture, Field Operations of the Bureau of Soils, 1921.

[13] Clarence Lounsbury, W. E. McLendon and J. W. Kerr have the following to say of the 70,912 acres of Cecil clay loam found in Union County, South Carolina ("Soil Survey of Union County, South Carolina," U. S. Department of Agriculture, Field Operations, Bureau of Soils, 1914): "The Cecil clay loam is formed largely by erosion, which has more or less completely removed the original sandy surface. It is an erosion-type, formed from areas

FIG. 11. SAME SOIL AS IN FIG. 9

BUT WITH LESS ACTIVE EROSION DUE TO MORE FLATTISH SURFACE AND THE PRESENCE OF A 92 PER CENT. GROUND COVER OF VEGETATION. THIS AREA (2.9 FT. × 4.4 FT.) ALSO HAS LOST IN EXCESS OF 4 FEET OF SOIL AND SUBSOIL BY EROSION. THE VEGETATION SHOWS THE FOLLOWING ESTIMATED DISTRIBUTION, WITH REFERENCE TO AREA OF GROUND COVERED: POVERTY GRASS (*Danthonia spicata*), 75 PER CENT.; POVERTY GRASS (*Aristida dichotoma*), 15 PER CENT. GROUND LICHEN, 2 PER CENT.; BARE SURFACE, 8 PER CENT.

turally (relative content of soil particles of various standardized diameters), but structurally as well. On the basis of studies pertaining to disturbed forest conditions at the erosion experiment stations (Fig. 2), on the same or similar soils, the most important structural change due to excessive erosion, from the standpoint of plant response, is a marked diminution of the effective pore space and an enormously increased tendency of the exposed clay subsoil to run together while saturated, and to bake and crack during dry periods, with consequent serious losses of available moisture. Most of the original forest of hardwoods was removed long ago from the 209,152 acres of Cecil sandy clay loam of Spartanburg County. Now about 60 per cent. of this land is under cultivation, the remainder being largely covered with old-field pine. There is an occasional second-growth white oak, hickory or dogwood and here and there are thickets of blackberry, plum, sassafras and smilax.

which formerly consisted of the more sandy types of the Cecil series."

IN THE NORTHERN APPALACHIANS

On November 6, 1931, a forester and a soil specialist of the State of Ohio, an agricultural engineer from the U. S. Department of Agriculture and the writer walked over the erosion-denuded slopes of a large section about three miles northeast of Roseville, in the Appalachians of southeastern Ohio. From one point the view took in an abandoned area of approximately two square miles. All this had been cultivated and once was considered good soil. A fine stand of hardwoods was cut from the area long ago. Remnants of such woodlands attested the fact. Now these lands are

abandoned. The soil over the greater part has been worn away, down to a mixture of clay and shale. On this grows, principally, goldenrod, poverty grass (*Danthonia spicata*), dewberry and blackberry. Patches here and there are bare of vegetation. These lands are very acid; nutritious grasses are so scarce that a large proportion of the land is not even used for pasturage. The prevailing type of cover is of a kind that permits continuing erosion, although at a slower rate than from bare ground.

In remaining clumps of the original forest type is a good ground cover of forest litter, below this a half-inch layer of duff (mixed vegetable matter and mineral soil) and beneath the latter a 7- to 9-inch layer of yellow-brown mel-

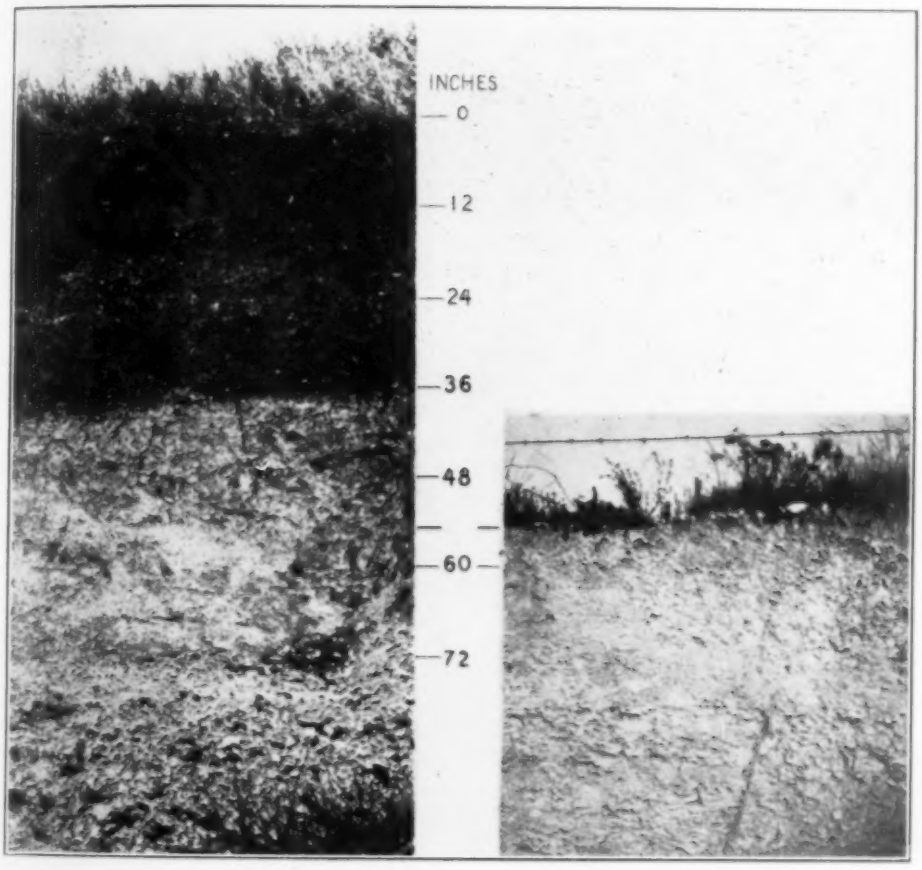

FIG. 12. VIRGIN (LEFT) AND SEVERELY ERODED (RIGHT) HOUSTON BLACK CLAY, TEXAS

BOTH AREAS ORIGINALLY WERE THE SAME, OCCUPYING A 3½ PER CENT. SLOPE. ABOUT 54 INCHES OF SOIL AND SUBSOIL HAVE BEEN REMOVED FROM THE ERODED AREA, FOLLOWING ABOUT 40 YEARS OF CULTIVATION. THE VEGETATION ON THE VIRGIN SOIL IS LARGELY COMPOSED OF GRASSES, WITH 96 PER CENT. OF THE SURFACE AREA COVERED; WHILE THAT ON THE EROSION-EXPOSED CHALK TO RIGHT (CORRESPONDING TO THE SUBSTRATUM OF THE VIRGIN AREA, AS INDICATED ON THE SCALE) SUPPORTS PRINCIPALLY WEEDS, 60 PER CENT. OF THE GROUND BEING BARE.

FIG. 13. VIRGIN GRASSLAND (HOUSTON BLACK CLAY, NEAR TEMPLE, TEXAS).

ONLY 5 PER CENT. OF THE GROUND SURFACE OF THIS REPRESENTATIVE SMALL SURVEYED PLOT IS BARE OF VEGETATION; GRASSES COVER 84.5 PER CENT. OF THE SURFACE (LITTLE BLUESTEM TAKING UP 43 PER CENT. AND BIG BLUESTEM 32 PER CENT.), LEGUMES 2.5 PER CENT., AND WEEDS 8 PER CENT. FRESH LAND OF THIS TYPE PRODUCES AROUND ¾ TO 1 BALE OF COTTON PER ACRE.

low silt loam, which, in turn, is underlain by from 5 to 11 inches of buff-colored silty clay and finally by a mixture of pale-yellow, acid clay and partly decayed shale fragments. This lowest section corresponds to the material now exposed over the greater part of the two square miles of eroded slopes, as well as over many thousands of acres elsewhere throughout the county.

The question was asked: "What can be done with land of this kind?" The soils-crop specialist asserted that, without reseeding, a fair stand of bluegrass could be established with the addition of lime and superphosphate, at a cost of about $10 an acre, the grass coming in voluntarily, following such treatment. It was unanimously agreed that the average farmer could not afford this expenditure on such denuded land. The forester was of the opinion that, while it would be exceedingly difficult and entirely impractical to reestablish hardwoods forest on such infertile, acid soil, conifers could be established. Again, it was agreed that farmers probably would not, upon their own resources, do much in this direction. It was further agreed by all that it was too late to accomplish very much with soil-saving measures, since so little soil was left to conserve. In other words, the soil poverty brought about by cultivating these steep slopes without provision for erosion control, resulting in stripping off from 8 to 20 inches of soil and subsoil, was so extreme that this group of specialists was unable to decide what remedy, if any, might be resorted to in order to restore these submarginal lands to any considerable degree of productivity beyond that which nature might accomplish through a long process of partial control by whatever vegetation should come in spontaneously. The mag-

nitude of the problem unfolds itself when it is considered that in the one county where this worn-out land was found there are about 200,000 acres, once cultivated, now idle, over which this condition of erosion and degraded vegetation, or an approximation of it, obtains.

Much the same thing is taking place in numerous other parts of the northern Appalachian region. Several of the accompanying pictures (Figs. 7, 8, 9 and 11) show characteristic views of west-central New Jersey, in the Piedmont section, where erosion has seriously affected a large area.

Summing up the relation of erosion to vegetative changes over immense areas formerly occupied by hardwoods and mixed hardwoods-pine forests in eastern United States, these few observations and measurements give some conception of the wide-spread changes, such as have been, in almost countless localities, about as complete as could be imagined. The vast areas of erosion-exposed subsurface, subsoil and substratum materials represent newly formed soils—new plant habitats or environments, having scarcely a semblance to former conditions, and in comparison with which they are tremendously inferior.

Changes in Texas Black Belt

Much the same thing has happened in the more rolling parts of the prairies and plains west of the Eastern forests. When it is considered that one rain, on May 10, 1930, removed 23 tons per acre of black soil (actual measurement) from a 4 per cent. slope (*i.e.*, having a fall of four feet in a hundred) of the central Texas Black Belt (Fig. 2), near Temple; and, further, that every rain causing

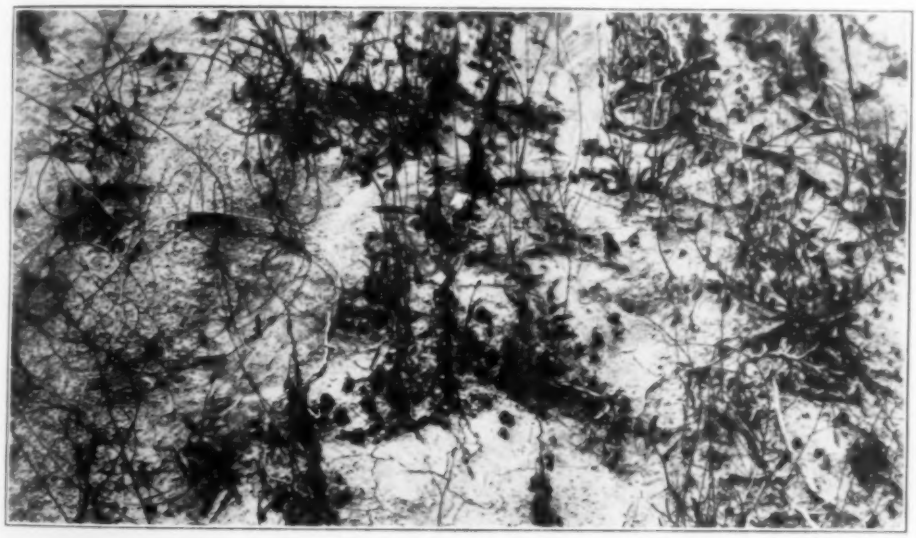

FIG. 14. DEEPLY ERODED CLAY (ORIGINALLY SAME AS THAT IN FIG. 13)

CULTIVATED UNTIL BLACK TOPSOIL HAD WASHED OFF, THEN ABANDONED (4 YEARS PREVIOUSLY). OF THIS SURVEYED AREA (SAME SIZE AS FOR THAT OF FIG. 13), 75 PER CENT. OF THE GROUND SURFACE WAS BARE OF VEGETATION. THERE WERE NO GRASSES, BUT WEEDS OCCUPIED 25 PER CENT. OF THE SURFACE. LAND LIKE THIS PRODUCES ONLY ABOUT 1/10 OF A BALE OF COTTON PER ACRE AS AN AVERAGE.

FIG. 15. VIRGIN SHELBY LOAM (NORTHWESTERN MISSOURI) WITH DENSE TURF OF BLUEGRASS (RECENT GULLYING DUE TO EXCESSIVE RUNOFF FROM CULTIVATED LAND ALONG RIDGE CREST).

FIG. 16. CORN FAILURE ON SEVERELY ERODED SHELBY LOAM (PHOTOGRAPH MADE IN AUGUST); SAME FARM AS SHOWN IN FIG. 15.

runoffs from those areas devoted to clean-tilled crops carries away a load of topsoil, it is not at all difficult to interpret the changes now rapidly taking place in this great area of originally highly productive prairie soil—the transmutation from a genuine "black belt" to a patchy composite of rich black soil, less productive yellow clay subsoil and comparatively unproductive whitish chalk (or marl) of the erosion-exposed deep substratum (Fig. 10). The virgin soil was densely matted with nutritious prairie grasses, which in spring and early summer were beautifully sprinkled with numerous species of flowers. On the other hand, the exposed whitish chalk, resulting from forty to fifty years' cultivation, now supports sparse stands of vegetation, consisting largely of impalatable weeds; while the erosion-bared subsoil proper, the intervening layer, supports chiefly weeds and stunted grasses, with a relatively high proportion of unoccupied ground surface. The virgin soil produced upwards of a bale of cotton per acre; the exposed chalk produces at the rate of about one tenth of a bale per acre in years of favorable rainfall and at the rate of about one twentieth to one fortieth of a bale in dry years.

The results of carefully made vegetation surveys on the principal soils of the region (the Houston black clay and its exposed sublayers, as chalk and Sumter clay),[14] employing small plots of equal size (surveys carried out on same date, summer of 1931),[15] in Bell County, Texas, are given in Table 1. These surveys were made to determine as accurately as possible the vegetative changes which have taken place as the direct result of soil washing in the region (Fig. 12). The conditions revealed are duplicated, or essentially duplicated, in numerous instances (Figs. 13 and 14) throughout the extensive rolling parts of the Texas Black Belt. In connection with the changes shown in this table, it should be observed that true chalk is not present at the surface of the areas studied. Where the chalk is actually exposed, the percentage of bare ground is relatively larger than where only the yellowish-brown subsoil clay (Sumter clay) is exposed, the composition of the cover is more largely of weedy growth, and recovery with respect to reestablishment of grasses, following abandonment, has been, generally, much less.

[14] For description of Houston black clay see: W. T. Carter, M. W. Beck, E. H. Templin and H. W. Hawker, "Soil Survey of Milam County, Texas," U. S. Department of Agriculture, No. 25, Series 1925, Bureau of Chemistry and Soils.

[15] Surveys of H. V. Geib, U. S. Department of Agriculture, Bureau of Chemistry and Soils, Blackland Station, Temple, Texas, and Simon E. Wolff, Texas Agricultural Experiment Station.

Changes in the Shelby Loam Region

The Shelby loam, a glacial drift soil,[16] of northern Missouri, southern Iowa, northeastern Kansas and southeastern Nebraska (Fig. 2), originally was densely covered with bluegrass (Fig. 15), growing on dark-colored, mellow loam, highly charged with organic matter. Under continuous cropping to corn, this rich topsoil has been swept from innumerable areas by erosion, down to yellow clay subsoil, within a period of about 50 to 60 years, on 4 per cent. slopes, and in about 10 to 20 years on 8 per cent. slopes. The exposed stiff, yellow clay produces little grass of any value and only about 20 bushels of corn per acre (no corn in dry years), as against more than 50 bushels for the best years on the less severely washed soil (see Figs. 16 and 17).

[16] For description of the Shelby loam see: H. H. Kruzekopf, R. C. Doneghue and M. M. McCool: "Soil Survey of DeKalb County, Missouri," U. S. Department of Agriculture Field Operations, Bureau of Soils, 1914.

TABLE 1

COMPOSITION AND GROUND-COVER, VEGETATION ON VIRGIN AND SEVERELY ERODED HOUSTON BLACK CLAY, BELL COUNTY, TEXAS
(Eroded areas, though originally Houston black clay, now represent Sumter clay)

Ground condition	No. 1: Virgin grassland, 2–3% slope			No. 2: Severely sheet eroded, with some gullies, 3–8% slope			No. 3: 11–18 in. of soil and subsoil removed, 6–7% slope		
	Ground	Common name	Botanical name	Ground	Common name	Botanical name	Ground	Common name	Botanical name
	Per cent.			Per cent.			Per cent.		
Bare	6		.....	35		.....	60	.....	.....
Grass Cover	93	65 Indian grass	Sorghastrum nutans	6	Buffalo grass	Bulbilis dactyloides	1	Silver beardgrass	Andropogon saccharoides
		14 Little bluestem	Andropogon scoparius						
		9 Drummond dropseed	Sporobolus drummondii						
		4 Silver beardgrass	Andropogon saccharoides						
		Three-awn grass	Aristida sp.						
		Needlegrass	Stipa leucotricha						
		1 Big bluestem	Andropogon furcatus						
		Buffalo grass	Bulbilis dactyloides						
Weed Cover	1	Sensitive-briar	Morongia angustata	34	Snakeweed (Texas broomweed)	Gutierrezia texana	39	18 Wreath aster	Aster multiflorus
		Kuhnia	Kuhnia glutinosa		Snakeweed (broomweed)	Gutierrezia dracunculoides		13 One-seed croton	Croton monanthyogynus
		Ruellia	Ruellia tuberosa	20	.....	Hartmannia sp.		4 Kuhnia	Kuhnia glutinosa
		Prairie clover	Petalostemum multiflorum	3	One-seed croton	Croton monanthyogynus		2.75 Texas lupine (blue bonnet)	Lupinus subcarnosus (L. texensis)
		Gum elastic	Bumelia lanuginosa		Beebalm	Monarda sp.		1 Annual sunflower	Helianthus annuus
		Great azure sage	Salvia pitcheri		Annual sunflower	Helianthus annuus		.25 Spurge	Euphorbia bicolor
		.....	Vincetoxicum biflorum	59	Hoary bindweed	Convolvulus incanus			
					Spurge	Euphorbia malaca			
				2	Spurge	Euphorbia serpens			
					Nodding spurge	Euphorbia nutans			
					Ironweed	Vernonia interior			
					Hoarhound	Marrubium vulgare			
	(Practically worthless, sometimes affording a little spring grazing.)						(Formerly cultivated, now abandoned. Not plowed or grazed for 4 years.)		

TABLE 2

COMPOSITION AND GROUND COVER, VEGETATION ON VIRGIN AND ERODED SOIL, TREGO COUNTY, KANSAS

Ground condition	No. 1: Virgin grassland			No. 5: 6–10 in. topsoil removed			No. 6: All of topsoil and part of subsoil removed		
	Ground cover	Common name	Botanical name	Ground cover	Common name	Botanical name	Ground cover	Common name	Botanical name
	Per cent.			Per cent.			Per cent.		
Bare	0	.....	.....	85			95		
Grass Cover	85	80 Buffalo grass	Bulbilis dactyloides						
		10 Little bluestem	Andropogon scoparius						
		10 Blue grama	Bouteloua gracilis						
Weed Cover	15	60 Common ragweed	Ambrosia elatior	8	85 Redroot amaranth (pigweed)	Amaranthus retroflexus	2	80 Redroot amaranth (pigweed)	Amaranthus retroflexus
		30 Little barley	Hordeum pusillum		10 Witchgrass	Panicum capillare		20 Witchgrass	Panicum capillare
		10 Daisy fleabane	Erigeron annuus		5 Russian-thistle	Salsola pestifer			
Old Kaffir Stubble				7			3		
							(Abandoned several years)		

The vegetative changes resulting from erosion on this extensive prairie soil have been extremely violent: a change from almost exclusive stands of bluegrass, in density of 100 per cent. ground cover, to scattering stands of weeds and dwarfed grasses of very low grazing value.

EROSION AND VEGETATION IN WESTERN KANSAS

The effects of erosion with respect to soil removal in the western Kansas wheat belt are illustrated by an erosion survey (Fig. 18) of a 159-acre farm in Township 13 S, Trego County, Kansas, completed in 1931.[17]

The virgin grassland of this area, that of the upland part of Class No. 7, Fig. 18, consists of dark brown, mellow silt loam (Colby silt loam), averaging about 12 inches deep. The material beneath this top layer consists of brown silty clay, which at approximately 22 inches below the surface passes into light-brown silty clay of a limey nature. The cultivated portion of this tract, representing a typical area of highly productive western Kansas wheat soil, was broken out of plains "short grass" in 1922, just ten years prior to the making of the erosion survey. All the eroded areas are now washing at a considerably accelerated rate, as compared with the rate measured at the Hays Station on practically virgin soil of the same original type occupying about the same slope. All of the eroded areas on this Trego County farm have been markedly reduced in productivity, the most severely washed portion being excessively droughty and having very low value for the regional crops. The composition of the present vegetation on the typical virgin land, on moderately eroded land and on severely eroded land (the last formerly cultivated but now untilled), all of which originally was nearly the same with respect to soil and slope, is shown, respectively, under sites Nos. 1, 5 and 6 in Table 2.

With respect to ground cover, the change from virgin grassland condition, site No. 1, to deeply eroded, unpro-

[17] By R. H. Davis, "Soil Erosion and Moisture Conservation Investigations," U. S. Department of Agriculture, Bureau of Chemistry and Soils, Hays, Kansas, Erosion Station.

ductive land, of the class representing site No. 6, comes within 5 per cent. of amounting to a complete reversal of the virgin condition: a switch from a condition of 100 per cent. vegetated surface to 95 per cent. non-vegetated surface. The vegetation on both of the eroded sites, Nos. 5 and 6, contains not a single plant that was found in the native sod (all three plots are of equal area). This condition of change, even though approximating an extreme change, is to be seen in numerous localities within the Kansas plains, on former grassland areas. Actually, it is fairly representative of the average situation on the abandoned eroded areas of the region.

Significance of Humus Ground Cover

Reference has been made to the higher organic-matter content and greater alkalinity of the immediate surface soil, as compared with the subsoil, of various important forested soils. It might be added that the content of phosphorus is often higher, also, in this superficial layer.[18] Beyond the important fact that the mineral surface soil normally is the most productive part of the profile, the humus ground cover is a feature of enormous importance in connection with soil permanency, *i.e.*, soil protection from washing. The work of Phillips and Goddard[19] at the Red Plains Erosion Experiment Station, near Guthrie, Oklahoma, gives some conception of the true significance of ground covers. At this station the forest-litter was burned from a measured area of post-oak timber in the spring of 1930, after the area had been surrounded by a waterproof metal guard, except at the lower end, where all the runoff and washoff emptied into a tank. Another area immediately alongside the burned plot, having the same forest canopy, was similarly put under control, and left undisturbed, with its natural ground cover of leaves and twigs. In May of the same year, during a period of almost continuous rainfall, the runoff from the unburned plot was at the rate of 250 gallons per acre, while the runoff from the burned plot, having the same soil and slope, was at the rate of 27,600 gallons per acre. The excess of runoff from the burned area over that from the unburned area, plus the water-holding capacity of the leaf-litter covering the latter site,[20] was approximately 90 tons per acre. The runoff from the former area was essentially clear, while that from the burned-over ground was muddied with the products of erosion. Thus, the effectiveness of a thin cover of leaves as a protector of the soil is seen to be far greater than commonly has been supposed, and, as Lowdermilk has recently pointed out,[21] the chief function of such a ground cover is not merely to absorb water, but to send down clear water into the soil, rather than muddy water such as fills up and chokes the pore spaces developed through normal processes of soil building (as holes formed by decaying roots, insects and worms, and the natural pores that go with a mellow, humus-charged soil).

The losses from these plots for the two years 1930 and 1931 (averaged) have been: From the unburned plot, .08 per cent. of the total precipitation and .01 ton of soil per acre; from the burned

[18] See H. H. Bennett, "Cultural Changes in Soils from the Standpoint of Erosion." *Jour. Am. Soc. of Agronomy*, Vol. 23, No. 6, 1931.

[19] Unpublished data obtained at the Guthrie, Oklahoma, Soil Erosion Experiment Station by S. W. Phillips, U. S. Bureau of Chemistry and Soils, Superintendent of Station, and I. T. Goddard, Oklahoma Agricultural and Mechanical College.

[20] The cover of leaf-litter and mold was found to have a water-absorption capacity of 33,331 pounds, or 16.7 tons, per acre.

[21] W. C. Lowdermilk, "Influence of Forest Litter on Runoff, Percolation and Erosion." *Journal of Forestry*, XXVIII, No. 4, 1930.

FIG. 17. EROSION-EXPOSED CLAY SUBSOIL OF SHELBY LOAM

SUN-BAKED, CRACKED AND DRY—EXCEEDINGLY POOR SOIL: CLOSE-UP OF FIELD WHERE MAN STANDS IN FIG. 16.

plot, 2.43 per cent. of the precipitation and .15 ton of soil per acre.

In this connection, it might be mentioned that the slow rate of surface-soil building under natural conditions is indicated in the measurements of the Missouri Agricultural Experiment Station, where a 7-inch layer of topsoil (of the Shelby loam type) is removed by erosion from land sloping about four feet in a hundred, used continuously for corn, in approximately 49 years (at the rate of an annual acre loss of 20.5 tons of topsoil); as compared with about 3,000 years (annual acre-loss of .35 tons of topsoil) required to remove the same depth of surface material from bluegrass sod. Since a good sod of bluegrass probably closely approximates the ground condition obtaining where normal soil building goes on, under the humid climate of the Shelby soil region, it seems reasonable to assume that continuous corn farming as practiced by many operators in northern Missouri and southern Iowa, is causing soil losses in one year equal to a minimum of about 400 years of natural soil building.

The investigations now being carried on at all of the erosion experiment stations show that a cover of grass has a powerful effect in holding both water and soil on the slopes. For example, at the Red Plains Erosion Experiment Station, Oklahoma, the runoff from Vernon fine sandy loam,[22] occupying a 7-per cent. slope, averaged for 1930 and 1931 13.16 per cent. of the total rainfall from land cultivated continuously to cotton, as against only 1.65 per cent., for the corresponding period, from land continuously covered with Bermuda grass. The corresponding losses by erosion were 14.57 tons and .037 ton per acre, respectively. The virgin soil of the same slope and type produced for this period

[22] For description of the Vernon fine sandy loam, see W. B. Cobb and H. W. Hawker, Soil Survey of Payne County, Oklahoma, U. S. Department of Agriculture, Field Operations, Bureau of Soils, 1916.

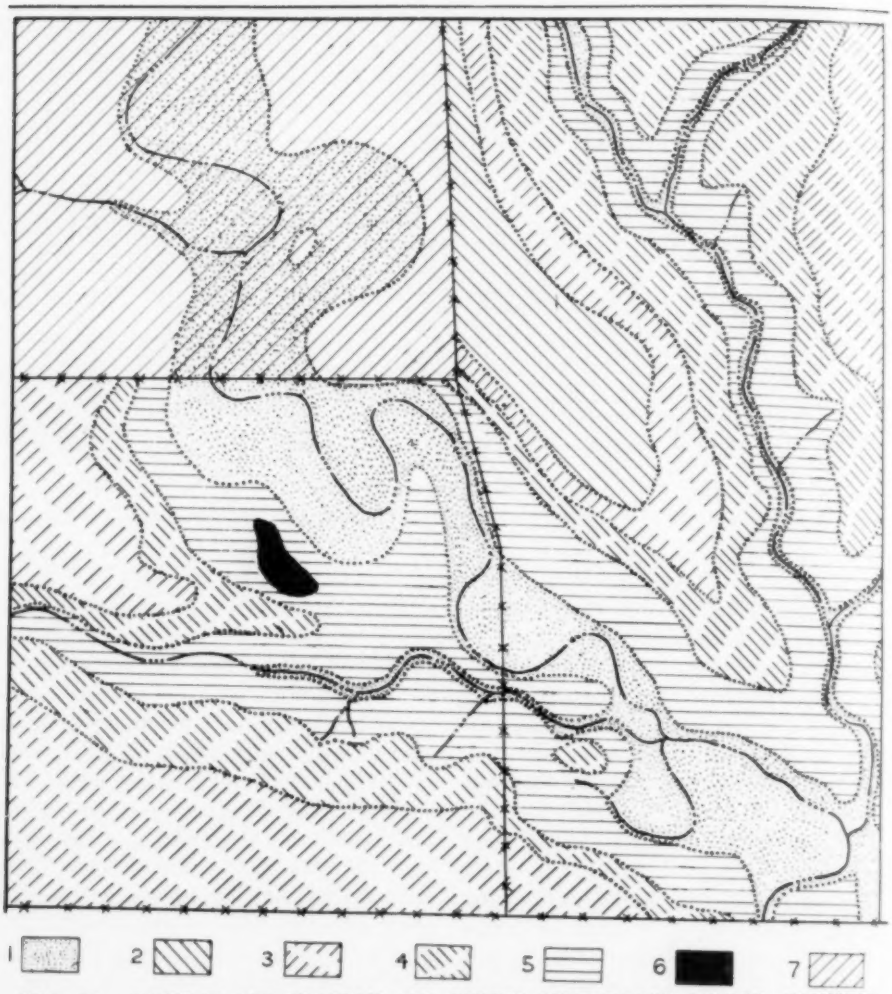

FIG. 18. EFFECT OF EROSION ON COLBY SILT LOAM, TREGO COUNTY, KANSAS

1, STREAM ALLUVIUM—NO EROSION BUT CONSIDERABLE DEPOSITION OF EROSIONAL MATERIAL (35.08 ACRES); 2, LEVEL, CULTIVATED—VERY LITTLE EROSION (7.7 ACRES); 3, GENTLY SLOPING, CULTIVATED—3 INCHES OF SOIL REMOVED BY EROSION (31.04 ACRES); 4, MODERATELY STEEP, CULTIVATED—3 TO 6 INCHES OF SOIL REMOVED (30.6 ACRES); 5, MODERATELY STEEP, CULTIVATED—6 TO 10 INCHES OF SOIL REMOVED (35.84 ACRES); 6, MODERATELY STEEP, CULTIVATED—ALL OF SOIL AND PART OF SUBSOIL REMOVED, DOWN TO 24 INCHES BELOW THE SURFACE (.5 ACRE); 7, LEVEL, AND SLOPING UPLAND AND LEVEL ALLUVIUM—VIRGIN GRASSLAND SHOWING NO EROSION (18.04 ACRES).

an average of 199.8 pounds of lint cotton per acre, while with the same rainfall the eroded subsoil, occupying the same slope (originally consisting of the same soil) averaged only 113.2 pounds per acre.

At the Bethany, Missouri, Erosion Station (Fig. 2), on Shelby loam of 8-per cent. slope, the water and soil losses, during 1931, from land devoted continuously to corn, were: 30.1 per cent. of the total precipitation and 84.08 tons of soil per acre (from a slope 73 feet long); whereas, the corresponding losses from the same soil, occupying the same slope and receiving the same rainfall, were, from continuous alfalfa: .36 per cent. of the precipitation and 2.18 tons of soil per acre. In other words, the densely growing alfalfa, constituting an excellent protective vegetative cover, held back and effected the disposal of 83 times as much of the rainfall as was retained on the corn land (chiefly by way of soil absorption and percolation), and caused, also, the saving of 38 times as much soil. The yield of oats per acre under the same conditions, for 1931, was 41 bushels per acre on virgin soil and 9 bushels on soil desurfaced down to clay subsoil.

At the West-central Kansas Erosion Station (Fig. 2), the losses of precipitational water (snow and rain) from a 5-per cent. slope of Colby silty clay loam, during 1931, were: from clean-tilled Kafir corn 11.79 per cent. of the total precipitation and 20.85 tons of soil per acre; whereas, the corresponding losses from undisturbed native sod (bluestem and other grasses, plus a few weeds) were only .05 per cent. of the precipitation and .0025 ton of soil per acre. Thus, the native plains-grass cover effected a soil-disposal of 236 times as much rain water as Kafir and caused the saving of 8,340 times as much soil. Artificially desurfaced soil (10 inches of surface soil removed) of the same original type and occupying the same slope (alongside of the Kafir and native-sod areas) lost, in 1931, 15.43 per cent. of

FIG. 19. ALMOST COMPLETE DESTRUCTION OF VEGETATION BY OVERGRAZING, SOUTH-CENTRAL NEW MEXICO

FIG. 20. RECOVERY OF VEGETATION

ON SAME CHARACTER OF LAND AS THAT SHOWN IN FIG. 19, CLOSE BY, AFTER A FEW YEARS OF PROTECTION FROM GRAZING.

FIG. 21. SHOWING RECOVERY OF GRASS ON PROTECTED AREA

NEAR THE JORNADO RANGE RESERVE (U. S. FOREST SERVICE), NEW MEXICO.

the precipitation and 3.4 tons of soil per acre. Wheat grown under the same controlled conditions (on normal soil in the same group of plots) lost, in 1931, 2.79 per cent. of the precipitation and .27 ton of soil per acre. The acreage yield of wheat obtained from these controlled plots, in 1931, was 26.7 bushels an acre from normal soil and only 5 bushels from desurfaced soil.

Soil Moisture

Absorption and retention of moisture within the soil, in amounts available to plants, constitute a complex problem, dependent on numerous variables, such as soil texture, structure and consistence, subsoil porosity or impermeability, character of vegetation, rate of evaporation, etc. It is not possible to discuss this phase of the problem in detail here; as a matter of fact the data available are not yet adequate for drawing final conclusions. The problem is being carefully investigated, however, on the soil-type basis, at the eleven soil erosion experiment stations located in various major soil regions (Fig. 2).

To illustrate the indicated moisture performance with respect to eroded and uneroded soil, two examples will be cited:

On April 10, 1931, the beginning of the cropping season (corn in this instance), uneroded Houston black clay, at the Temple, Texas, Erosion Station, contained 23.5 per cent. of moisture, as against 16.8 per cent. in the adjacent area of eroded soil (of the same original type). The moisture in the normal soil continued to exceed that in the eroded soil throughout the growing season, until about the time the corn began to mature, when that contained in the normal soil dropped below that contained in the eroded soil, *i.e.*, to 13.8 per cent., as against 15.9 per cent. The fact that the uneroded soil produced seven times as much corn as the eroded soil, undoubtedly explains the reversal of the moisture situation toward the end of the growing season.

On Vernon fine sandy loam, at the Red Plains Erosion Station, the soil-moisture behavior for virgin and eroded land was quite different during 1931. At about the beginning of the cotton season (May 13), the virgin soil contained nearly the same amount of moisture as the eroded soil, *i.e.*, 15.08 per cent., as against 15.38 per cent.; at harvest time (September 1), however, the uneroded soil showed a moisture content of 5.91 per cent., as against 7.12 per cent. for the eroded soil. The fact that the virgin soil produced approximately 77 per cent. more of lint cotton per acre than the eroded soil, indicates that moisture drainage by vegetative growth was very much heavier on the former. Beyond this, the moisture contents referred to do not at all mean that the total amount present was available to plants. The probability is that a considerably smaller proportion of the water enclosed within the smaller interstices of the clay of the eroded areas was available to the plants than of that contained within the larger pore spaces of the much coarser grained sandy surface soil in the virgin area. So, even with its higher moisture content, the probability is that the exposed subsoil clay, in its moisture decline from 15 per cent. at planting time to 7 per cent. at harvest time, actually lost more *effective moisture* than did the sandy surface soil, with its corresponding decline from 15 to 6 per cent.

Changes in the Southwest

In the vast domain of grazing country represented by the arid Southwest, erosion following over-grazing has caused severe denudation of an enormous area of uplands, with consequent vegetative changes, such as have seriously reduced

the grazing capacity of millions of acres of formerly fair to good range country,[23] even to the extent of 100 per cent. damage in some localities. So tremendous has been the vegetative change in consequence of this evil that it is impossible to undertake any comprehensive statement of the details here. There are areas in southwestern Texas and various parts of New Mexico, Arizona, Utah, California and other western states over which the vegetation has been completely destroyed, with little evidence of any important recovery following years of comparative freedom from invasion by live stock. Usually, however, protection from further grazing is followed by slow recovery, even from an essentially bare initial condition, to a stage where there is sufficient recuperation for the plants to give considerable protection from erosion (Figs. 19, 20 and 21). Some areas which have been swept almost bare of plant cover make a remarkable comeback under protection, due to the soil, underground seepage from higher areas and other local conditions. Such second-growth vegetation, however, is often markedly different from the original cover, particularly with respect to various nutritious grasses characterizing the original condition.

During the summer of 1929 a heavy downpour of rain six miles southeast of Panguitch, in southern Utah, swept from a 50-per cent. slope of sheep range country practically all of the grass. In many places the soil, a brown gravelly sandy loam possessing considerable mellowness, was gouged out to depths of 10 inches or more (18 inches in places). Samples collected the day following this erosive rain (August 16) showed in the uneroded soil, which had been conserved during that particular rain by protec-

[23] See H. H. Bennett and W. R. Chapline, "Soil Erosion a National Menace." Circular No. 33, U. S. Department of Agriculture, 1928.

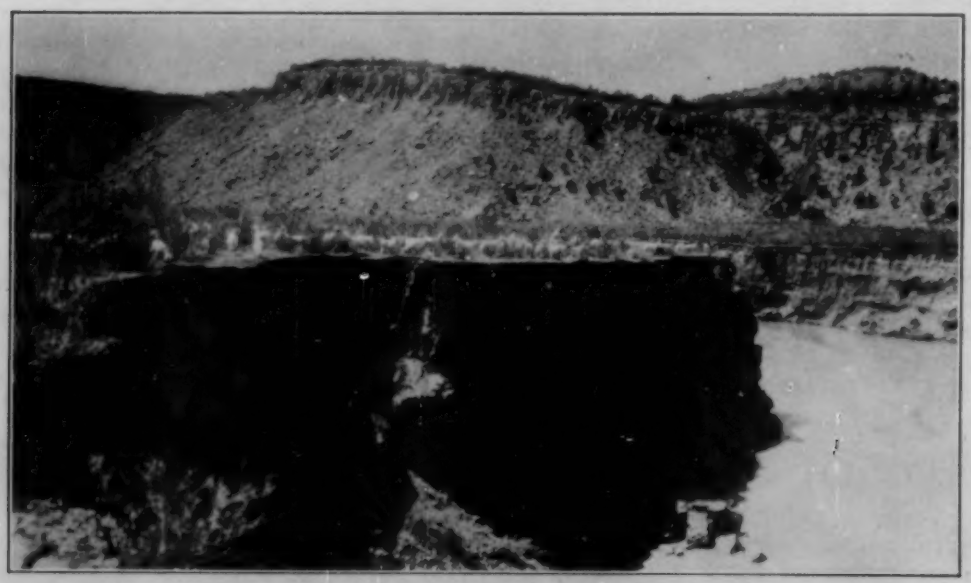

FIG. 22. METHOD OF OVERGRAZING ALONG THE PUERCO RIVER, NEW MEXICO

MOST OF THE ALLUVIAL PLAIN HAS BEEN SWEPT OUT FROM THIS POINT, AND THIS SINCE THE COMING OF WHITE MAN TO THE REGION.

FIG. 23. SEVEN FEET OF SAND

LAID DOWN IN THE TOWN OF SAN MARCIAL, NEW MEXICO, BY THE 1929 FLOOD IN THE RIO GRANDE. LARGE AREAS WERE COVERED BY THESE DEPOSITS.

tive clumps of sage, an organic matter content of 1.4 per cent., as against .4 per cent. in the exposed lighter colored subsurface material (from which 10 inches of soil had been washed off). Such eroded areas were locally appraised as having little further value for grazing. It was asserted that grass would come back with exceeding slowness on slopes thus denuded.

Depletion of the upland vegetation has brought about a very serious problem in the alluvial plains of almost countless valleys throughout this great western grazing region. Excessive run-off from the denuded slopes has had the effect of trenching many valley plains, formerly well-vegetated, with broad channel-ways and lateral arroyos, where, 40 or 50 years ago, there was either no channel or only a diminutive run-way. In many places these channels have undercut and widened to such degree that the entire valley floor has been riddled or bodily swept out, from the foot of the uplands on one side to the corresponding position on the other side (Fig. 22). Soil, whose accumulation has taken millenniums under the slow natural process of valley filling, has been torn away completely or stripped of its productive surface material to the extent of wholly changing the vegetation remaining, or that subsequently established, for an undetermined period. Scattered creosote bushes and a few other woody shrubs are all that can be seen over some of the denuded areas which formerly were densely vegetated with nutritious grasses and herbaceous growth. This process of partial and essentially complete devastation of soil and vegetation is continuing steadily. There still remains, in some localities, enough land of approximately virgin characteristics to verify, unmistakably, what the changes have been; in other localities, where the original conditions have been essentially obliterated, there is abundant historic proof of the alterations. The student of soil conditions needs no historic proof, however, to mea-

FIG. 24. THIS FIELD OF ANTHONY SANDY LOAM

WAS CHANGED TO GILA CLAY BY THE 1929 FLOOD ALONG THE RIO GRANDE, NEW MEXICO. HERE 12 INCHES OF DENSE, STICKY CLAY WERE DEPOSITED OVER THE LOOSE SANDY SOIL.

sure the violent changes that have taken place in such areas as that of the Puerco River Valley in New Mexico, for example. Here the valley plain is fast being gouged out, and there are large areas of adjacent slopes, now nearly bare of vegetation, where the soil has been largely swept away (as shown by what is left about the protected base of an occasional brushy tree).

Changes Due to Silting

In the fall of 1929 a very destructive flood swept down the Rio Grande. The Bureau of Chemistry and Soils had completed a detailed soil survey of the alluvial plain from about the head of water in Elephant Butte Reservoir to about 11 miles above the confluence of the Rio Grande with the Rio Puerco. This flood covered so much of the surveyed area with clay and sand that most of it had to be resurveyed in 1930.[24] Areas that had been mapped as clay were changed to loose sand (Fig. 23), and sandy lands were deeply buried with clay (Fig. 24). In some places the depth of freshly deposited sand was as much as seven feet, while clay was laid down in strata exceeding two feet. Thus, droughty soils were changed to soils of good moisture retentiveness, and *vice versa*. The vegetation will necessarily undergo accordant changes.

Effect of Lowering the Watertable

Another phase of erosional effect on vegetation is represented by the lowering of the watertable following the gouging out of deep channels. A striking example is to be seen in Cañada de los Álamos, north of Los Angeles, California. Here an old arroyo, recently becoming active, cut its channel to a depth of 50 feet or more into the porous materials of alluvial and colluvial origin. The violent lowering of the watertable resulting from this channeling so changed the moisture condition that many cottonwoods of large size have recently died (Fig. 25). Similar effect on vegetation is clearly observable along the Puerco (New Mexico) and numerous other western streams.

Effect of Over-wash

A very large proportion of the alluvial plains in the Piedmont region (as well as of many other regions) has been so altered by over-wash derived from the eroding regional slopes that the soil, and

[24] E. N. Poulson and E. G. Fitzpatrick, "Soil Survey of the Socorro and Rio Puerco Areas, New Mexico." U. S. Department of Agriculture, No. 2, Series 1929, Bureau of Chemistry and Soils.

the vegetation on it, has been markedly changed. Soil that formerly consisted of loam has been buried deeply by sands of varying texture, clay deposits and silt, all so variable, both on the surface and through vertical section, that it has been impossible to classify most of the areas within the Piedmont as uniform soil types. Moreover, such land (classed as *meadow* in soil surveys) has been converted into swamp or semi-swamp by the increased overflows resulting from the clogging of stream channels with erosional débris. Formerly, these alluvial areas were heavily timbered with ash, sycamore, oak, sweet gum and pine. Much of the land was put into cultivation and considered the best of the region. Since abandonment, following the changes referred to, most of this has grown up to thickets of willow, alder, birch, blackberry, pine, rushes, cat-tail and coarse grasses.

Conclusion

Abnormal soil erosion is an impoverishing process of tremendous potency. It impoverishes the soil as well as the vegetation (including crops) that grows on it. It is hoped that this paper has presented sufficient evidence pertaining to the far-reaching effects of erosion in altering the environmental conditions of plant life to stimulate increased investigational interest in this branch of science. It should be added that, while this accentuated washing can not be completely controlled, it can be slowed down very considerably where there is a will. In determining the most effective and economic measures for accomplishing this, study of the enormous restraining capacity of vegetation, with respect to maintenance of soil and storage of water on sloping areas, opens a wide field for research and applied science.

FIG. 25. COTTONWOODS DEAD (ON RIGHT)

AS RESULT OF THE LOWERING OF THE WATERTABLE BY THE RECENT ENLARGEMENT OF THIS CHANNEL (NOW MORE THAN 50 FEET DEEP IN PLACES): THE CAÑADA DE LOS ÁLAMOS, NORTH OF LOS ANGELES, CALIFORNIA. INCREASED EROSION HERE APPARENTLY THE RESULT OF MORE RAPID RUNOFF DUE TO OVERGRAZING OF WATERSHED.

SOME PROBLEMS OF STREET AND HIGHWAY

By Dr. KNIGHT DUNLAP

PROFESSOR OF EXPERIMENTAL PSYCHOLOGY, THE JOHNS HOPKINS UNIVERSITY

THE interest of psychologists in the complex problems centering about the motor car was early aroused, and the division of anthropology and psychology of the National Research Council took official cognizance of this interest and its importance in 1924 through Dr. R. S. Woodworth, then chairman of the division. A committee on the psychology of the highway was organized in that year and delegates from the division participated in the first National Conference on Street and Highway Safety. I was the first chairman of the divisional committee, and was one of the delegates to the first and later conferences.

During the years 1927–29, I succeeded in transferring the chairmanship to Dr. A. P. Weiss, but his lamented death brought me in again. Now, the need for a younger and more active chairman has become clear, and Dr. A. R. Lauer, of Iowa State College, one of the most energetic and competent men in this field of work, will undertake the job, while I will continue to serve on the committee.

In the early years of its existence, the committee confined itself to advisory work. This was due partly to the kaleidoscopic changes in the organizations (of which there were many) studying traffic problems, and to our desire not to complicate the situation still more. In an advisory capacity we were able to supply information on various points to engineering and other organizations. In those days, the notion of increasing safety by more rigid examinations for drivers' licenses was prevalent. I believe we rendered useful service by showing that the realization of this ideal is not so simple as it appeared, and by emphasizing the impracticability of examination going beyond the minimal test of driving ability and elementary knowledge of the rules of the road.

Another matter where the dissemination of knowledge was important was in regard to signal colors. We were able to bring to the attention of the strategic groups the fact that the standards of color formerly in use were especially unfortunate, and that tests for color blindness were quite useless. The point we constantly made was that the "red" and the "green" can be made quite adequate for color-blind persons, and that the more adequate for them, the better they are for normal drivers, since it is a peculiarity of normal vision that when we direct the eyes a few degrees in any direction away from a small colored object such as a traffic light, the colors appear to us practically as they do to the typical "color-blind" person. The newer color standards are still not adequate, but we will shortly have available data from which adequate standards may be prescribed.

In 1927 conditions were more nearly clarified so that it seemed proper to commence research on leading problems. A donation of a few thousand dollars from the American Optometrical Association for work on the effects of defective vision of drivers made the time especially opportune. Dr. Weiss was interested; and Ohio State University relieved him of a part of his teaching time that he might undertake this work. With the assistance of Dr. H. F. Burtt

and Mr. A. R. Lauer, a program of basic research was commenced, and Ohio State University provided facilities and support in a gratifying way. State highway officials and individual organizations, notably the Dayton Light and Power Company, cooperated and made donations. The illness of Dr. Weiss disorganized the program, and his death and the move of Dr. Lauer to Iowa State College brought it to a close. The work on defects of vision had been forwarded, and important methods of reducing accidents in groups of commercial drivers had been inaugurated by the Dayton Company through the cooperation of Mr. Shriver and Dr. Lauer; and a number of analytic investigations contributory to the fundamental problem of the driver's relation to safety were completed. These were published in a monograph by Ohio State University in 1930. I might add that the methods worked out in Dayton have since reduced the accidents to drivers from the Dayton Light and Power Company 50 per cent., with the discharge of not many drivers. This work this year is being extended to other corporations.

Ohio State University was picked for a central research station for several reasons. Its location is sufficiently central; there seemed a chance for cooperation with important agencies; and it also seemed probable that an experimental driving field could be installed close to the university. I have always believed that such a field is essential, since laboratory tests, although an indispensable means of progress, need checking under controlled driving conditions.

With Dr. Lauer's great interest and increasing ability in the work, it seemed expedient to consider building up an experimental center at the Iowa State College at Ames. The distance from eastern centers seemed prohibitive at first, but the other advantages have finally outweighed this objection. Dr. Evans, the head of the psychology department, was much interested, and the college administration was entirely sympathetic. The results so far are highly satisfactory. A driving field has been supplied on the college tract, and substantial resources of other sorts are available, within the limited means of the college. Cooperation with the State Roads Commission and with many other agencies of state-wide or local nature seems adequate.

Work on the standardizing of signal colors is in progress. A study on proper ground colors for road signs has been completed, reported to the U. S. Bureau of Roads, and will shortly be published. Arrangements have just been made with the Iowa State Automobile Commission and the police department and traffic courts of Des Moines, through which the work on the effects of defective vision will be pushed to completion. A study of minor information signs, now a considerable danger to traffic, has been begun. A study of the legibility of license plates of different lettering and color combinations has been completed with the cooperation of the U. S. Bureau of Roads. Other investigations are on the docket.

Not all our experimental work has been confined to Ohio and Iowa. One result in Baltimore has been the working out by Inspector Lurtz of a model system of parking signs, which require no reading, but inform the drivers almost a block away as to parking limitations in the particular block. This system has been in operation for several years, and a check which we made this year shows it satisfactory and useful to drivers. Work is in progress also in Baltimore on semaphore requirements, and on headlighting and auxiliary lighting systems.

Here you have a picture of what psy-

chologists, after long analysis of the problems and careful planning, are doing in regard to traffic problems. Perhaps it is not at all what you might expect psychologists to be interested in. Psychologists are irritating in that way. They are always doing what they are not expected to do. Many people, apparently, expect psychologists to be interested in a sort of abstract "Psychology of the driver." There is no such topic, except as an abstraction; and we are not interested in abstractions. A driver is a human being, who does certain things in certain situations: situations composed of roads, cars, pedestrians, dogs, etc. You can no more study the psychology of the driver aside from these conditions than you can study insect pests apart from their breeding grounds, their available foods and their parasites.

The first thing the psychologist does, then, if he proceeds intelligently, is to analyze driving conditions; relate the requirements they make to known abilities of human beings; and then seek to find how the requirements may be bettered to suit human capacities and known human tendencies. When he finds the human ability in respect to a certain requirement is not known, then the determination of the ability is an important matter.

Next, he will take up the question of what to do about requirements which can not be adapted to the general range of the drivers, and study the problem of adaptation of the drivers themselves and the problem of elimination of unadaptable drivers. Here we run into problems of maximal complexity and difficulty. It is not a question, on the one hand, of educating drivers who are anxious to be educated. It is not, on the other hand, a question of tests of capacity which, adequately administered, would pick out the drivers who ought to be ruled off the road. Both of those problems are relatively simple. But they have really very little to do with our problem of improving traffic conditions. There are certain exceptions to this broad statement which I will indicate, but these exceptions have only minor bearing on our major problem.

The problems in which this committee has made progress illustrate very well the actual point of view of the psychologist. The street and road conditions and the particular types of cars in use make certain requirements on drivers. If these requirements are not met, there is trouble.

Now, drivers are human beings covering certain ranges of capacities and education and temperamental peculiarities. They are not standardized: there is a wide range of drivers in all these respects. If the drivers, or a considerable proportion of them, do not meet the requirements of traffic, there are two theoretical lines of progress—(1) to change the drivers; (2) to change the requirements. In the first case again, there are two possibilities. We may improve the abilities of individual drivers, through some educative process. On the other hand, we might improve the average, in another way—by eliminating the worst individuals.

On both of these points I shall have more to say, but I should like to point out here that the problem of color standards illustrates the complexity of the situation. You can't improve color vision in any individual. On the other hand, you can not by any practicable means eliminate the color-blind individuals. You can, however, change street and road conditions so that the requirements can be adequately met by the color-blind drivers. The course to take is then perfectly obvious.

The adapting of the color requirements to the driver, however, requires a competent study of the driver. No road

or street conditions have any absolute significance. They are significant only in regard to the drivers who will be placed in those conditions. We must know exactly what the color-blind man can do and can not do. Further, we must know exactly what the normal man can do in direct vision and in slightly oblique vision. This is essential to the determination of the proper conditions.

This, you may say, is a simple physiological problem. As a matter of fact, the physiological problem involved is not only unsolved, but is of no particular consequence for the practical problem. I may point out that even the determination of whether a man is or is not color blind is primarily a psychological problem, and there is no physiological test which can be applied except under tedious laboratory conditions. Determination of a man's practical color vision by simple tests is a tricky matter in which the psychologist's knowledge of the types of human reaction to test conditions is invaluable.

In studying the total traffic situation three principles have slowly clarified themselves to the psychologists.

(1) *We do not expect to increase safety except in an incidental way.* Safety is an excellent ideal, but an elusive one. Improvements in conditions do expedite traffic and make it flow more smoothly; and may make safe driving easier to attain. As soon, however, as the expediting of traffic decreases hazards, traffic immediately takes up the slack.

Let me illustrate. On a certain highway, a two-lane road, traffic became highly congested, and accidents frequent. It was widened to a four-lane road, and can now accommodate from four to eight times the traffic of the old road, with smoother flow; and it is easier driving. Was safety increased by this improvement? For a short time only. Before long, accidents began to be as numerous as ever before, and more violent. If two cars collide, several more pile on top of them. Extra efforts have been made recently by the state police, through wholesale arrests, to decrease accidents by limiting speed. Will this succeed? Look back over similar campaigns elsewhere, and answer the question yourself. Moreover, speed is only a part of the problem.

Another illustration might be found in four-wheel brakes. These expedite and smooth traffic. They have not, however, reduced the number of accidents. They have merely expedited and smoothed traffic. Other illustrations can be found, but are needless.

(2) *Under present conditions, which we see no way of changing, few persons can be prevented from obtaining driver's licenses; and any extensive attempt to limit drivers is doomed to failure.* Certain defectives—the blind, the legless, etc., can be excluded. But these are the ones who don't think that they can drive anyhow. Epileptics and a few others can be excluded theoretically, since a considerable public sentiment would be behind the exclusion. That epileptics are excluded generally, except the cases which are of a rather obvious nature, is improbable. The deaf are apparently better than average drivers. A few types, oddly enough, who are safe as the average drivers (the color blind, for example), are theoretically excluded in some states (but most color-blind persons get by the test). Any attempt to apply special capacity tests rigidly would produce a revolution, and of course would be absurd anyhow.

We believe that it is worth while to consider the practicability of efforts to determine and exclude epileptics and other specific defectives, and other cases constituting known risks. How this can be done is not at present clear.

A great number of preventable accidents and annoyances to other drivers, however, are due to reckless, erratic and ignorant drivers. These drivers are in no wise to be classed as physical or mental defectives or as lacking in capacity. Theoretically, tests could be devised for the identification of the worst of these classes. I do not even doubt that the tests could be developed practically, if a number of competent psychologists devoted their energies to it. The application of such tests, however, is another matter. We know the difficulty in keeping even the simplest tests up to standard, and we know that the administration of complex tests of sufficient precision to be determinative of mental conditions would require a vast army of skilled experts who are not available and will not be available. Under any other conditions of administration such tests would be a mere stench. Tests to be useful, or at least harmless, must be such as can be applied by the usual deputy, of modest education and political appointment. We can be certain that, for the issuing of drivers' licenses, tests can not be usefully applied which go beyond: (a) a practical driving test; (b) a few questions on the rules of the road; and (c) a test of ability to read English. The only importance of the first two of these tests, as they are administered, is that candidates do take driving lessons before coming up for examination, and do look at the book of rules. That candidates of greater competency may be flunked, and some of lesser ability passed, is true; but it doesn't matter much. Those who are flunked can try again; and the vital point is that all know they may be flunked.

Where tests which are theoretically searching, even along these lines, are attempted, they break down. This is evident from results in at least one state, which has a system of examination which appears to be excellent, but which is a farce in actual operation.

(3) *In this situation, much can still be done towards making safe driving as simple and easy as possible for all drivers.* If we make it simple for the dull or ignorant drivers, it is better for the more intelligent drivers, and *vice versa.* Further, since obstructed, erratic and tangled traffic is in itself a nuisance, and also increases the difficulties for competent and well-meaning drivers, anything we can do to smooth traffic is worth while. These seem to be the real problems of traffic and these should be emphasized.

From the psychological point of view, therefore, we must: first, determine where driving conditions can be made simpler and easier for all drivers; second, we must find out the points on which certain drivers are ignorant, and promote the instruction of these drivers; third, we must consider means by which laws can be enforced—an important matter which is of particular interest to the psychologist. Finally, the minor problem of excluding a few drivers is to be faced.

In what respects can driving be made simpler than it now is? I shall enumerate a few. (1) Traffic lights must be of the colors most quickly discernible by all drivers. Their form and placement are highly important and must be worked out on the basis of the human beings' habit of perception. When we know what the driver needs, the engineers can fill the prescription with no trouble at all. The present forms and placements of semaphores are by no means satisfactory. Accidents due to this cause may be infrequent (although it is really difficult to determine the extent to which the semaphore condition does contribute to accidents); but present conditions do confuse traffic in many cases, while in many others the requirements are such as to take drivers'

attention away from other and highly important matters. Conditions can be improved.

(2) Information signs must be conspicuous, and they must be independent of reading as far as possible. Where reading is essential, something must be done to make the reading simple. The handling of route numbers at present is excellent. But in most states local signs are sources of danger. If a driver must slow down, or stop at an intersection to study a blackboard containing a list of names of villages or a flock of arrows on a post, he makes trouble for himself and others.

An adequate system involves the consideration of what the average driver can do. It involves much more than the question of whether the blackboard of one state or the flock of arrows of another is the worse. It involves the psychological problems of background and lettering, of the systematic arrangements of names and, above all, of placement. The problem of a uniform system can be solved and is now under investigation.

(3) A great deal has been accomplished by road engineers by the use of dividing lines. These don't deter the reckless drivers, but they assist the drivers who want to be careful. I do not think this problem is finally solved.

(4) Cautionary and instructive material spread on the street surface is a nuisance. The driver who is driving properly doesn't read it: if he studies the street surface in cities it distracts him from the more important jobs. The least snow or even a sheet of water abolishes the literature, anyhow.

(5) Body designs of up-to-date cars introduce needless difficulties. The average driver who won't keep over to his side of the road may be merely hoggish, but in many cases, he really is afraid to get over, because he doesn't know where his wheels are. I know this seems absurd to the engineer whose specialty is body design; but that is because he isn't an average driver. If the designers can't cut windows lower, and set the radiator hood down, and give greater depth to the windshield, and so make the driving problem simpler without weakening the body materially, then they are not as smart as I believe they really are.

(6) Road edges have a material bearing on road-hogging. With the money spent on concrete roads, the neglect of road edges is nothing less than scandalous. In many places where cars have "gotten out of control" and so have swerved off the road and overturned, I have noticed that the road edge is the key to the catastrophe. Loose gravel, a drop of two to four inches—such conditions are common. If a car going 35 miles an hour slips a wheel off the road, will it get out of control? We all know that it will unless the driver is expecting it, or is an unusually expert driver. The results are not merely many wrecks, but also an increase in the general fear on the part of the average driver of getting over to his side of the road, especially with present cars, where the driver sits down in a closed pen looking over the high edges.

While I am on these topics, I can't refrain from referring to a road condition which has no bearing on my main problem, but which is a fertile source of fatal accidents. I refer to the solid concrete copings ("death walls" they are), which are built on the sides of culverts and small bridges. In most cases, if the driver should run his car off into the creek at one of these places, he would have a chance for his life. When he smashes into the end of the wall he has no chance at all. Some of these walls have been the cause of death after death. The same amount of concrete laid down flat, extending the width of the roadway, would have a real value.

Let us turn now to the question of ignorance. In Maryland, if the driver ahead of me hauls over to the left at an intersection, I assume that he is preparing for a right turn. If he hauls over to the right side, I assume that he is going to make a left turn. In the majority of cases, I am correct. In some cases, this is mere carelessness or disregard of the rights of other drivers. In a great many cases, however, it is just stupidity. Of course, the driver can make his turn with less trouble to himself and at higher speed in this way. I suspect that the danger and the difficulty caused to other drivers usually doesn't dawn on him. As long as everybody does it, nothing can be done about the insolent or reckless driver when he does the same thing. I have some grounds for supposing that a large number of drivers are really amenable to reason on this point; but the technique of applying the reason has to be carefully planned. In some places white-lining the intersection into alleys solves the problem: but in many streets this can not be done.

The use of hand signals is another matter in which education is important. The passing of laws doesn't seem to be an adequate remedy for this condition. On the other hand, some much-advocated systems are really dangerous. The inclination of the arm is harmless so long as you don't assume that the driver means what he seems to mean. Finger systems are a nuisance. Yet adequate systems are possible. Moving the arm up and down for *stop* and *right turn* (that is all the more difficult rotary movement amounts to), and a more or less straight and definitely motionless arm for *left turn* are definite signals. Any driver can tell whether his arm is rigid or moving, but many a man, and still more women, don't know whether the arm points up, down or straight out.

One more item of this sort, and I will leave the topic. The horn nuisance constitutes a problem which is apparently minor, yet has serious bearing and is probably responsible for more serious accidents than might be supposed. Safety and comfort would probably be enhanced by banning horns entirely, since there are few situations in which the horn is a protection, and very many situations in which it is a nuisance. It does not seem possible, however, at present to achieve this reform. This is one of those interesting points at which an accepted theory, handed down from the horse age, prevents people from observing facts. Certain ameliorations, however, might be effected. The London law, which prohibits the blowing of a horn while the car is at rest, is excellent, because it is a law which is readily enforceable. This reduces the nuisance, but it does not reduce the number of fool drivers who make horn-tooting a substitute for careful driving. A meter on every horn, with a nickel for each toot, would be something of a deterrent, but I fear is impracticable. Some means of educating drivers is the practicable solution. I think it is really a matter of ignorance on the part of most horn-tooters.

The problem of educating drivers has been discussed from many angles by many organizations, commercial and scientific. There seems to be a general agreement that two agencies are practical, from the strictly educational point of view. One is the movie, the other is the radio. From the commercial point of view, however, these do not seem so practical after all. Negotiations with film producers and distributors, I know, have been undertaken by several agencies, without success. There have been some films presented in a small way, but that sort of presentation does not cover the situation. On the other hand, it is clear that nothing stuffed

down the people's throats, or rather, into their ears and eyes, will have the desired effect. On this point, the hard-boiled attitude of the film producers is correct. I believe, moreover, that the plans proposed so far have been fundamentally wrong. Long films of a didactic type are out of date. The public is bored by them. On the other hand, there is a distinct possibility of both interesting the public and impressing them, through short episodes, one to be shown each week, each episode complete in itself and snappily worked out. I believe this method should be considered well, and with the cooperation of the auto trade a producer could be made to see its points. Nothing less than national distribution with periodic presentation would be worth while, however.

The radio has been employed a great deal in total, but not in a systematic way. Many safety addresses have been made over local systems. Here again, sporadic addresses are not productive. "Listening in" is more or less accidental, especially when the public expects the worst; and if the speaker does arouse interest this interest is not capitalized. Nothing less than a major chain broadcast, at an hour of the day when men listen, with a fifteen-minute address once a week for six to twelve weeks is worth the trouble. If such an arrangement were made, the circulation of the printed speeches in booklet form afterwards would be possible and could be easily accomplished.

In our cities, there are pressing problems of traffic, peculiarly urban. The baffling parts of these problems are their psychological features. I suppose most of the intelligent city traffic directors know the formal solutions of these problems. I know at least some directors that do; but they are helpless. Public opinion is chaotic, and steps towards the solutions can be taken only slowly, as conditions get so bad that the public recognizes that what it considers drastic steps are unavoidable.

The street surface is limited. The only traffic plan that can provide for even the immediate future is the one that makes the maximal use of this limited surface. If you use the street for garage space, you can't use it for traffic. A bus carrying forty passengers occupies no more space than two private cars carrying two persons each, or less. I have counted cars at critical points in New York, Boston, Philadelphia, Washington and other cities, at various hours of the day, and have been impressed by the fact that the majority, except in a few wholesale districts, are private cars, carrying an average of less than one person; and if chauffeurs are counted out, the average in many cases falls below one passenger. Taxis are not nearly so numerous, except immediately around railroad stations, as their bright colors would make them seem; and commercial vehicles are well in the minority, even in down-town New York.

If cars are parked solidly for the whole block in which a merchant is established, his customers can't come to his store by car. And yet merchants are convinced that congestion in front of their stores helps their business in some mysterious way.

The trouble is that the typical American wants a lot of conflicting things. He wants to be able to jump in his car, drive wherever he likes, and park his car exactly on the spot when he gets there. He wants to go as fast as he pleases, and let the devil take other drivers and pedestrians. He doesn't want the use of his car restricted, and fights every attempt to straighten out the mess, until the mess gets so bad that he finds he is wofully hampered anyhow.

This situation is quite familiar to the social psychologist. Whenever there is conflict in the satisfaction of desires, there is chaos, until it is beaten into men

that in a social group there can be no adequate satisfaction without adjustment of each man's activities to those of others. This means limitation for all, but is the only method which gives the maximal satisfaction. With every new conflict, however, we forget the lessons which past adjustments should have taught us, and each man strives to satisfy his own desires at the expense of others and fights violently against the inevitable process of social adjustment. So we have a variety of suggestions for putting the other fellow out of the way. Some have raised the cry: "Limit the use of the street by commercial vehicles," forgetting that commercial traffic is the life blood of the city. Others clamor: "Restrict street cars," "Restrict busses," although street cars and busses are the greatest economizers of precious street space. "Limit taxicabs;" in fact, each man wants to limit anything, limit everything, which will leave him more free to drive and park at will.

The remedies: In the first place, we must recognize that the real problem in cities is no longer traffic, but transportation—transportation of the maximal quantity of persons and commodities in the smoothest way. We must stop worrying about moving the maximal number of cars, and consider the most efficient means of transportation. In the second place, street space is public space, and any one who desires to use it to the exclusion or inconvenience of others must expect that within a very few years he will have to pay for the privilege. We do pay, in property taxes and gas taxes; but this is for using streets and roads as traffic lanes. For the special privilege of blocking the street with my parked car, I shall eventually have to pay rental on the space I preempt. When this principle is established—I say *when*, not *if;* for it is as certain as death—there will be plenty of capital invested in garages to take cars off the street. Definite adoption in any city of a plan of parking-space rental which should begin with a minimal charge for parking privilege tags with definite increases yearly to a reasonable limit would start a building program right now which would be an aid in this period of depression.

In the third place, we may look forward to the prohibition of private passenger vehicles from important areas in the cities, where the needs of commercial and passenger transportation can not permit this street-wasting traffic. Five years ago, traffic directors thought I was crazy when I prophesied this. They don't think so now.

These and many other readjustments are in sight. They should not come as a succession of shocks, as violent and disruptive readjustments of conditions which will have become intolerable. The public should be educated to understand the necessities and the values of the solution. The changes which are involved require readjustments of capital, readjustments of personal habits and readjustments of city systems, all of which will consume time and need planning ahead in order to prevent disastrous losses and severe inconvenience. But if the situation is not understood, if the comprehensive plans are not made, the losses and the inconveniences which must surely occur are inestimable.

All transportation in a civilized community depends on laws and law enforcement. Law enforcement is a tricky thing. Laws can be arbitrarily enforced under certain conditions, but those conditions are of brief duration, especially in a civilized community. Laws which are not accepted as reasonable and necessary by the majority of the citizens and which are not enforced uniformly are mere sources of evil, like the anachronistic blue laws of Maryland.

I do not recommend a servile obedience to law. An unreasonable, an unjust, an unfairly enforced law, it is the high duty of an American citizen to break; and if he is punished for it he ought to take his medicine like a man. All progress has been made through law-breaking. In no other way has the progressive adaptation of laws to new conditions been possible. The revolutionary patriots were law-breakers. So were all the martyrs. So are we all, although I fear most of us do not base our law-breaking on as high moral principles as did George Washington and the founders of Christianity.

I may cite the speed laws as an illustration. Was the speed limit raised from 14 miles an hour to 40 because it was seen that conditions warranted the change? No, indeed. The limits have been raised because everybody broke them, and spasms of arresting people not only did no good, but the injustice of "soaking" a few while others "got away with it" increased popular resentment. Public opinion was not behind the old speed limits, and a law without public opinion behind it would better be repealed *pronto*.

Traffic laws are essential: without them transportation would be demoralized. The question is: What laws, and how enforced? There is no simple answer to this question; and no useful answer can be obtained by appeal to formal jurisprudence. Solution of the problem involves consideration of rapidly changing mechanical situations, and a considerable amount of applied psychology.

(1) The law must fit the situation. Speed must not be prohibited where speed is a minor factor. I think Mr. Eynon of Pennsylvania has correctly estimated the situation for a state having an official speed limit. I understand that this is interpreted as a limit only where it endangers others than those in the car itself. In Maryland, the speed limit is 40, but if you drive as slowly as 40 you obstruct traffic, except during the irregular period when the police are pinching freely on a certain road. On the other hand, certain congested areas are posted for 35, for 25 and lesser numbers of miles per hour. But, practically, one is in greater danger of arrest in driving at 50 on the open road than at 40 in these highly dangerous stretches.

(2) The law must have a high degree of enforcement or be abandoned. Yet the usual speed law can not be enforced. What is the solution? Obviously, to concentrate enforcement on the dangerous stretches where the limits are low, and abandon the open road. This could be done. By concentrating on these important stretches, a real observance could be attained. A minimum of laws, really enforced, becomes respectable. More laws than can be enforced make no law at all.

What holds for speed limits holds for other aspects. Critical points should be watched. In certain cities, beating the green light became prevalent. A vigorous campaign of pinching stopped it because public sentiment was favorable. A parking limit is difficult to enforce: there are not enough policemen. But parking in forbidden places is easily detected and kept down. The whole parking problem must be faced on the basis of the determination of the rules which can be actually enforced, and abolishing other rules. Otherwise, the general flouting of regulations is inevitable.

(3) The relation of law officers to the public is the most important of all aspects in law enforcement. In some cities, the traffic cops delight in bawling drivers out; these cities are precisely those in which disregard of the most essential regulations is most flagrant. No drivers feel cooperative with the law after being treated roughly, and many

take a delight in repeating the offense in safer circumstances. This is especially evident where the offense has been due to confusion or awkwardness. On the other hand, where a different attitude is taken by the officers, cooperation is much better. Why the police force in some cities has never grasped this point is a matter I can't explain.

This hasty survey is intended to emphasize the complexity of the traffic problem, and show that there is a large place for the psychologist in cooperation with engineers, automobile makers, traffic directors, and not least, the public. It will readily be seen that it is not a field into which a psychologist can hastily plunge. No simple application of general principles is worth a fig. Nothing but prolonged study of the complex situation, leading to the picking out of vital problems, is of any consequence. There is room for active work by a number of men whose psychological training has been of the sort which fits them for the particular field. The field is great, and the workers are few. Why? Well, for one thing, because we have to do this kind of work for nothing, on our own spare time, in addition to our pretty heavy regular jobs. Naturally only a few, who get enough kick out of it to compensate for giving up almost all other amusements, Sundays and evenings included, are attracted. Another difficulty is that the more important problems require money for their running expenses, and it seems difficult to get money for this sort of work. Some of the brethren, moreover, look down on us because our efforts are not in the line of pure science.

PURE AIR FOR OUR CITIES[1]

By Dr. D. B. KEYES

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SOME time ago we were all shocked by the announcement in the newspapers that a catastrophe had occurred in the Meuse Valley in Belgium. A mysterious fog with apparent toxic properties settled down in the valley one day and caused wide-spread suffering and some deaths.

The whole world was alarmed by this catastrophe. A great many different theories were formulated by scientific men throughout this country and other countries as to the cause of this mysterious toxic fog.

It so happened that we were investigating in the Chemical Engineering Division of the Engineering Experiment Station at the University of Illinois the air pollution by sulfur dioxide formed from the sulfur contained in our Midwest coals. It was our theory at that time that sulfur dioxide from the burning of coal by industries and residences in this valley was oxidized in the atmosphere to sulfur trioxide and combined with the water in the fog to form sulfuric acid. In other words, the natives of this valley had been subjected to a rain of sulfuric acid. Apparently the atmospheric conditions were such that this oxidation could take place due to the presence of water and oxygen, and furthermore, that the sulfuric acid fell to the ground due largely to the lack of movement of air.

An official commission was formed in Belgium to investigate the catastrophe. They reported in the latter part of 1931. It is interesting to know that their final verdict on the cause of this calamity corresponded closely with our theory developed approximately a year ago.

[1] The author has based this article on the work of Professor H. F. Johnstone and Professor R. D. Snow, of the Chemical Engineering Division of the Engineering Experiment Station, University of Illinois.

We need not be alarmed that such a calamity will ever occur in our locality. The possibility of such a thing happening is extremely small when we recognize the fact that certain particular conditions must prevail in order to bring it about. We are, however, deeply interested in the general subject of air pollution because it is a well-recognized fact that the air in our cities is not what it should be.

Our scientific men, engineers and public officials should be congratulated on the able work that has been done in order to produce pure water for our towns and cities. On the other hand, they should be censored for their lack of interest in the problem of air purification. The residents of our large towns and cities are not only subjected to sulfur dioxide but are also required to breathe air containing a relatively high percentage of solids. This dust is not only detrimental to lung tissue and is undoubtedly the carrier of bacteria, but also it cuts down the sun's radiation to a very marked extent. One of the great problems of modern civilization is the purification of air for our cities.

This sulfur dioxide problem may be attacked in two ways; first, the removal of sulfur dioxide from the flue gases; second, the removal of sulfur from the fuel. We have done preliminary work along both lines at the University of Illinois. I am pleased to say that we have already obtained interesting and worthwhile results.

It is a well-known fact that sulfur dioxide in flue gases, even though it be present to the extent of only 0.3 per cent., may be eliminated by scrubbing the gases with water. The partial pressure of sulfur dioxide in water is unfortunately so high when it is present to any appreciable extent that it becomes

necessary to use enormous quantities of water. Extensive work along these lines has been done in connection with power plant development in England. Preliminary figures show that the cost of this operation is prohibitive.

Our investigators believed that it would be possible to change the sulfur dioxide to sulfur trioxide by oxidation using the oxygen present in the flue gas. Sulfur trioxide differs from sulfur dioxide in that its partial pressure in a water solution is small in comparison. It should therefore be possible to absorb the sulfur dioxide and a sufficient quantity of oxygen from the flue gases in water, in the presence of a suitable catalyst to convert the two to sulfur trioxide and sulfuric acid. Preliminary investigations have shown that both iron and manganese sulfate when present in relatively small amounts in the wash water are suitable catalysts for this particular reaction.

It was soon found, however, that there was an inhibitor present which prevented the catalyst from remaining active over a period of time. Investigations show that the inhibitor present in most flue gases was a phenolic substance. The next problem was the problem of removal of this inhibitor.

Many months were spent investigating a great many different schemes for removing this inhibitor. It was finally found that the application of a direct electric current over a short period of time would completely eliminate the inhibitor present in the wash water. An oxidation reaction takes place and apparently completely destroys the phenolic bodies. It is not necessary to apply the current except very occasionally and then for only a short period of time.

Laboratory tests and small scale tests in our power plant utilizing actual flue gases show that it is possible to eliminate approximately 95 per cent. of the sulfur dioxide present in our flue gases. These tests have also shown that one gallon of wash water will be able to treat approximately twenty-five hundred cubic feet of flue gas. This is considerably better than the results obtained in England. It is believed by men in the industry that such a process can be developed to a satisfactory scale and will become economically possible in its industrial utilization.

There are, however, other problems that must be solved before this utilization will be possible. For example, we have known that one of the great difficulties involved in large scale application of this process is the production of sufficient surface of contact between the liquids and the gases. This surface of contact is necessary in order to effect sufficient solution of the oxygen from the flue gases. A definite concentration of oxygen in the liquid is required for this reaction. We not only need sufficient contact surface but we also need sufficient time of contact. The rate of oxygen dissolution is relatively slow as compared to the more soluble gas, sulfur dioxide. This means, from a chemical engineering standpoint, that it is necessary to have scrubbing equipment which will permit a rapid changing of the liquid film.

It is recognized in all liquid gas reactions, whether they be physical or chemical, that two films exist which offer the greatest resistance towards diffusion of molecules. One is the gas film immediately above the liquid surface and the other is the liquid film immediately below the gas film. These two films are recognized to be practically stagnant under normal conditions. It is easily seen, therefore, why it is difficult for molecules, especially large ones, to pass through these films. It so happens with the less soluble gases, the liquid film is more resistant than the gas film. It will therefore be necessary to take this fact into account in the design of a suitable scrubber, and move the surface of the liquid constantly in order to minimize the liquid film. It will not be permitted to use the ordinary spray type of scrub-

ber because in this case the liquid film in the droplets remains practically stationary during the entire time of contact.

It is important, on the other hand, to utilize a type of scrubber with very little back pressure because the economics of handling these gases is such that it will be impossible for us to make use of any high pressure blowers or similar devices. In fact it is imperative to keep within a pressure not greater than that exhibited at the base of an ordinary flue. This eliminates from consideration the passage of the flue gases through a body of liquid, even though such a device would be satisfactory from the standpoint of elimination of the liquid film. Just exactly how this problem will be solved is not definitely known. We believe, however, there is a possibility of utilizing what is known as a filled column in which the liquid passes down through many channels, over the surface of a solid, coming in contact with the gases passing up.

It should be noted that whatever type of equipment is finally selected for the scrubbing of these gases it will be necessary, in all probability, to remove most of the solids present in the flue gases prior to their entrance into this equipment. Otherwise the equipment will soon become inefficient in its operation. This may be considered as a fortunate difficulty because in the last analysis the problem will never be solved until we not only remove the sulfur dioxide but all solid matter from the gases going to the atmosphere.

I have stood at the window on the upper floor of a tall building in New York City and noted the cloud overhanging the city was apparently not composed of carbon particles but inorganic matter—in terms of the power plant designer, fly ash. Analyses have shown that it is largely silica which is removed with great difficulty either by scrubbing processes or by electrical precipitation, the common methods now in use. The particles are extremely small and gravity methods are practically out of the question.

The natural conclusion is the scrubbing equipment must eliminate at least a portion of the solids from the flue gases. Experiments at the University of Illinois have indicated that the type of equipment which is necessary for the removal of the sulfur dioxide will probably remove most of the remaining solid particles.

It is my personal opinion that some of the sulfur dioxide which reaches the ground, coming originally from a flue, rides down on the surface of solid particles. We have no experimental evidence to prove or disapprove this statement. If this statement is true, any device for the removal of solid particles will materially help in the removal of sulfur dioxide.

It is recognized that no matter how successful we are in the elimination of sulfur dioxide from flue gases, the question of purifying the air in our large cities will never be completely answered by this work alone.

There are many thousands of residences in Chicago using coal as their source of heat. This coal has an appreciable percentage of sulfur and therefore if it became necessary to remove the sulfur dioxide, it would mean the installation of many thousands of scrubbing columns and chemical plants in the homes of Chicago. Such a thing from a practical and economic standpoint is utterly impossible.

It will be necessary to remove the sulfur from the coal before it is burned, a very difficult problem, in order to remedy the entire situation. We have done considerable research work in the Chemical Engineering Division here at the University of Illinois on this subject.

It is well known that there are two types of sulfur present in our Mid-west coal, one pyritic sulfur and the other so-called organic sulfur. This organic sulfur has never been isolated. No one has

ever seen it. No one has the least idea what its composition is. It is called organic sulfur because of its tendency to dissolve in certain organic solvents and because it can not be mechanically separated from the carbon and hydrogen compounds.

The pyritic sulfur can be removed to a certain extent by the well-known coal washing processes. If coal is finely pulverized so that the particles are somewhat similar in size, the pyrite, having a considerably greater density, has a tendency to fall faster through a water or any other medium than the coal particle. This is the basis of coal-washing processes.

Various engineering concerns have developed these washing processes until they have become wonderfully efficient. We can expect, however, to eliminate not much more than 20 to 25 per cent. of the total sulfur in the coal by such a process. In those cases in which mechanical cleaning is economically feasible, we feel that as much as possible of the sulfur should be removed by that method. However, even after the maximum beneficiation obtainable by mechanical cleaning has been accomplished, there still remains in the coal all the organic sulfur and also the sulfur present in the form of fine pyrite particles widely disseminated throughout the coal substance and hence not amenable to mechanical treatment. For the removal of the sulfur present in these forms, other methods of sulfur elimination, presumably involving chemical changes, must be devised.

To begin with, the pyritic sulfur can be oxidized by air when the ground coal is suspended in water, the oxidation products being largely soluble sulfates. We have found at the University of Illinois that certain catalysts speed up this reaction. Of course the higher the temperature, the faster such a reaction. It is believed possible that such a process might remove as much as 50 per cent. of the total sulfur. Unfortunately the dissolving of the sulfur oxidation products from the coal particle without the addition of mineral acids is a long and tedious process. The sulfate clings tenaciously to the surface of the carbon particle. In other words, the salt is highly adsorbed on the surface. This difficulty may prevent the process being used alone.

The ordinary coking process for coal has a tendency to drive off some sulfur. However, in the presence of such reactive gases as hydrogen, a large proportion of the sulfur is eliminated in the form of hydrogen sulfide which can be easily absorbed and removed. Our investigations at Illinois have shown that it is quite possible in the laboratory to remove approximately 60 per cent. of the sulfur in the form of hydrogen sulfide, by what might be termed an instantaneous coking process, using hydrogen or hydrogen-containing gas as the reagent. Crushed coal is allowed to fall through a zone through which hydrogen is passing. This, of course, must be done at relatively high temperatures.

It is especially interesting to note that coal treated by the air oxidation process formerly mentioned and then subjected to carbonization in hydrogen contains only approximately seven per cent. of its original sulfur. In other words, the combination of these two processes means a removal of approximately 93 per cent. of the sulfur.

It can not be said that the results so far obtained in our investigations prove conclusively that the economic removal of most of the sulfur from our Illinois and Mid-west coals is an assured fact. We do feel, however, that the results so far obtained indicate that such a process is possible, though it undoubtedly will take considerable time and energy before the difficulties involved are overcome.

These investigations should contribute materially to the final solution of the general problem of air pollution.

THE ORIGIN AND DESTINY OF ENERGY

By Dr. MASON E. HUFFORD

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ONLY a few years ago the leaders in physics had arrived at the conclusion that the greatest discoveries in physical science had already been made and that there was left for future research only a repetition of the earlier experiments, with that degree of patience and accuracy in the performance which would add certainty to one more decimal figure. Then came the discovery of x-rays and radioactivity and the isolation and measurement of electrons with all the epoch-making researches to which these gave rise. Now it is generally believed that there has been no period in the history of physics so fruitful of progress as the thirty years just passed. Physicists of to-day believe that many of the older experiments may, upon being repeated, disclose new facts and new suggestions for investigation, that no physical law is a finished and closed fact. In any of the experiments of fifty or a hundred years ago there may have been phenomena overlooked or residuals uninterpreted, which in the light of our day may be fruitful suggestions of a broader and more complete understanding.

With this present-day liberal attitude let us look at the problem of the origin and destiny of energy, to recall what notions were held regarding these concepts in the century just passed and to show how the problem is being solved in the light of the new physics of our day.

We have just witnessed the appropriate and very elaborate celebration, in London, of the centennial of the discovery by Michael Faraday of the relationship between electric currents and magnetic fields. We have had pointed out that the world in every phase has been revolutionized by that discovery. With equal appropriateness we might celebrate another discovery which barely preceded the work of Faraday, the discovery of the relation between heat and work, that is, the relation between heat energy and mechanical motion; and we might equally well say that the results of this discovery have been no less revolutionizing. In fact, the first half of the nineteenth century was marked by gigantic strides in all fields of scientific thought which have borne fruit for a hundred years and continue to stimulate the most active scientific minds of our own time. It is because of the fact that some of the ablest research of recent years has its roots back in the pioneer work of the previous century that it seems appropriate to call attention to the principal facts concerning the relation of heat and work and to the consequences of that relation.

If the students of to-day had lived only a little more than a century ago, they would have been taught that heat was a kind of fluid which could be given to or taken from bodies at will. Because the density of the heat fluid, caloric, was regarded as so immeasurably small, heat was classed along with the imponderables of that day. But such a misconception was destined to be short-lived. In fact, the whole classification of imponderables was but a blanket under which to hide want of information, and under the convincing argument of laboratory experiment it soon had to yield and disappear. Count Rumford, in boring cannon for the Austrian Government in 1798, proved that heat was developed in proportion as the boring tools became dull, and Sir Humphry Davy melted ice below the freezing temperature of water by no other means than the

friction developed by rubbing pieces of ice together. For forty years the nature of heat remained in question. Then Mayer, a German physician, observed that his patients in Europe yielded darker blood, when bled as a cure for fever, as compared to his patients in Java. He reasoned that in cooler climates greater bodily heat, accompanying better oxygenation of the blood, was secured at a greater expenditure of muscular activity. Mayer was able to make some calculations from some new work by Regnault at Paris on the specific heats of gases at constant volume and constant pressure, and these results proved his assumption that mechanical energy and heat energy can be converted, the one into the other. The next step was immediately forthcoming, that they are but manifestations of the same thing.

It should be stated that the brilliant and precise work of the English physicist Joule in 1840 finally established the identity of work and heat and their quantitative relation for all time. The experiments of Joule had as a background the theoretical work of Sadi Carnot. Carnot, a French engineer, published a paper in 1824, the results of careful observation and shrewd insight into the processes of nature which in the ideal state he called cyclical changes. He imagined that a body of perfect gas at high temperature might be drawn from a source, trapped in a closed sealed cylinder and allowed to expand. During the expansion heat disappears, temperature drops and mechanical work, that of increasing the volume of gas against resistance, is done. Now if the gas is put into the condition so the process can be repeated, it must be compressed. Compression will heat the gas, but if heat is abstracted in part, while the volume diminishes to that of the original, the temperature may be brought again to that at the beginning. The cycle has consisted in supplying heat while the gas in expansion is hot and taking it away while the gas in compression is cool, with the net result of a gain in work and a sacrifice in heat. Now the whole process of a heat-working device, which is the underlying principle of all nature's transformations as well as all man-made heat-operated machines, was summed up by Carnot in the statement that the efficiency of all heat-transforming devices is measured by dividing the heat which disappeared, that is, the quantity supplied minus the quantity rejected, by the quantity supplied. Another expression for this law of absolute efficiency is the second law of thermodynamics, which, to use the language of the German physicist, Clausius, says: "It is impossible for a self-acting machine, unaided by any external agency, to convey heat from one body to another at a higher temperature." It is clear that no heat-to-work transformation can be a hundred per cent. efficient unless there is no heat rejected, which means that when the transformation is complete the expanded gas must be absolutely cold, that is, at absolute zero, 273 degrees below the freezing temperature of water.

Now every one knows that we have, on the earth, no such ideal cold regions with which to surround our engines so that the efficiency is certain to be less than perfect. In fact, the difference between the temperature of source and sink is so small relatively that the best of our devices reaches only 50 per cent. or less. Whenever heat is drawn for the production of work it comes to us with a mortgage. That mortgage, when paid, represents the unavoidable loss. Further, due to loss by conduction and through friction, our ordinary machines entail a commission charge which must be added to the mortgage. This further increases the loss and drain on our sources of heat and raises the temperature of the sink. Every working machine we know therefore tends to

further the leveling of temperature of sources and sinks until at some distant day there must be a common temperature everywhere on the earth. From these conclusions it is clear, therefore, that from the foundations of the earth perpetual motion was outlawed.

And now look beyond the earth and consider what takes place among the stars. These are our greatest known sources of heat, of which our sun is one small example. For past eons of time these great white hot bodies have been pouring radiant energy into space. Under our older conception of limitless space this heat never could return. It meant that every blazing sun was surrounded by an infinity of volume into which the heat rays traveled forever. Here and there might be a planet which intercepted some of the radiation and whose temperature might therefore be raised, or a sun which captured a little more energy than it already had, only to pass it on again later, into the depths where its dissipation was complete.

Consideration of the fate of the heat of the universe led Clausius to speak of its inevitable loss as the "Wärmetod,"—the heat death; and Lord Kelvin, through similar reasoning, announced the general principle of the "Dissipation of Available Energy." According to this view, every century, indeed every year, sees our bank account of potential energy decreased and dissipated into heat and the heat radiated away beyond recovery, sees also a common temperature of the earth and the universe approaching. The activity of the universe, then, tends steadily toward a condition of stagnation, a "Götterdämmerung," in the language of the old German myth, which means the twilight of the gods, a condition of everlasting night when men and gods shall fall into endless rest and sleep.

And if Clausius and Kelvin have seen the picture as it is, then what of yesterday, a century ago, the beginning of our eon? There must have been a time when there was less heat energy, indeed a time when there was none. Our thought goes back to that morn of creation when the universe, wound up like a clock, was set going and before the second law of thermodynamics, with its inevitable dissipation, was made a statute. No better argument for the doctrine of the *deus ex machina* could be made. One can but wonder how much the second law and its consequences have had to do with the shaping of that doctrine. Our picture of the beginning and end of the universe is certain to be characterized by the limits of our own thinking. We attempt to base our conclusions upon facts as we see them, but the facts may not all be revealed. It will be remembered that Galileo's telescope showed the true relations of the sun, the planets and their satellites and completed the overthrow of the Ptolemaic system and established that of Copernicus.

For a period of nearly seventy-five years physicists have considered the problem of the origin and destiny of the energy of the universe. The idea that the heat of the sun and stars comes by their own combustion, as if their substance was burning coal or reacting chemicals, was early abandoned. The enormous rate of emission would bring them to cold dark bodies within a few hours or under the most favorable conditions within two or three years. More thoughtful consideration was given to the hypothesis that a rain of meteors on the sun's surface would account for the heat and light radiated. In 1854 Lord Kelvin published a calculation in which he showed that the sun's surface would necessarily acquire each year an additional layer of material sixty feet deep and that the newly received bodies must strike the sun with a velocity of 276 miles per second in order to produce the outflow of energy. It is doubtless true that some small fraction of the sun's

energy is produced in this way, but it is doubtful whether it is any considerable part of the whole.

A much more plausible theory of the origin of stellar energy was that of condensation. If the sun's mass was originally in the vapor state, vast amounts of energy must have been liberated while it contracted to the present size. In the light of the newer physics, Sir Arthur Eddington at Cambridge has determined an upper limit for the age of the sun from the energy produced by its contraction since a temperature of 3,000 degrees was reached. He concludes that the sun has existed for about twenty million years. While this is a vast period of time it will be seen that it is too small to meet the demands of the biologist, geologist and astronomer.

There have always been minds to which the "Wärmetod," the idea of the dissipation of available energy and the consequent asymptotic ending of the universe, is not satisfactory. There are those who doubt whether the second law of thermodynamics is always and everywhere true. Perhaps even now somewhere in the universe there is a source of potential energy, where new available energy and heat are being created. Whatever the final facts are found to be the ultimate end of the universe has been greatly postponed if not indefinitely removed. The down slope of the energy-time curve has been found to be much less than it was thought to be half a century ago.

One of the greatest contributors to our increased breadth of view is Einstein. Whatever challenge his theory of relativity may yet have to meet, we must admit that in much it has been signally victorious. One of its foremost successes is its prediction of the identity of matter and energy. Maxwell at Cambridge in 1881 predicted in his electromagnetic theory of light that a beam of radiation incident on an absorbing surface should exert pressure on that surface equal to the energy of the beam. Lebedew at Moscow and Nichols and Hull at Dartmouth experimentally verified the existence of light pressure and proved therefore that radiation has momentum, one of the defining properties of matter. The impact of the sun's radiant heat and light upon the earth exerts a force which totals 60,000 tons.

While we had left to us the ether of space so fundamental in Maxwell's theory, the momentum of light was associated with the mass of the ether and our concepts of matter and energy were separate, but since Einstein, in his theory of relativity, finds no need for the ether we now must identify the momentum with the light energy itself, which is to say, that matter and energy are the same thing. As a confirmatory proof of this identity, the eclipse expeditions of 1919 and 1922 reported that the light of stars was curved from its straight line path when passing close to the sun, exactly in accord with the calculations based on the theory of relativity. This has been regarded as strong proof of the material nature of radiant energy.

Assuming that matter and energy are the same, Sir James Jeans has shown that a body which radiates energy at the rate of 50 horse-power loses weight at the rate of one and one fourth grams per century. By the same calculation the sun is exhausting its mass at the rate of 250 millions of tons per minute. Therefore the sun weighs 360,000 million tons less to-day than yesterday. Five or ten million years ago our sun was twice as large as now.

In this process of direct transformation of matter into energy the method represents the maximum possible efficiency. Compared to it our engines yield about one one hundred millionth of one per cent. If a drop of water were wholly transformed to energy it would yield 200 horse-power continu-

ously for a year. On this basis a pound of coal would do the work for which we now require five million tons. In this process there is no sink, there is no ash, no heat waste, all mass becomes energy. Out of an atom an electron escapes to freedom and finding a like privileged positive ion, the two are paired in an everlasting union and annihilation—a train of waves starts across space. Atoms and electrons are done away, and in their stead there appears a blazing star.

In another important respect relativity has brought us a change in our point of view—that regarding the limits of space. What we formerly thought was an unlimited universe has come to be bounded and limited. Just as by measuring the curvature of a limited portion of the earth, its radius can be determined, so in an analogous way the density of the distribution of matter determines the size of the universe and shows that space is rounded back on itself. Some idea of the immensity of the universe may be obtained by measuring distances by the velocity of light. We know that light will travel seven times around the earth in a second. It will pass around the universe in 6,000 millions of millions of millions of years. If the earth were represented by the size of an atom, then the limits of our largest telescopes would be the radius of the earth, and the universe is a thousand million earths. This is a measure of our change of understanding of our universe since the time of the first astronomers.

Within the time in which our views regarding mass and space have changed, our ideas regarding the age of the earth have also been modified. No one now believes that the Biblical record of the earth's history was meant as an accurate statement of time. The infallible record is written in the earth's structure itself, although the interpretation is somewhat difficult. A seemingly successful method of measuring the age of the earth is offered by determining the ratio of quantities of uranium and lead found in the igneous rocks. The history of the method dates from the discovery of radioactive matter by the French physicist Becquerel, in 1896. About ten years later Rutherford and Soddy at Montreal showed that radium, which represents the fifth transformation of matter after uranium, disintegrates into two gases, radon and helium. The radon disintegrates in turn through four generations and finally becomes lead. From the rate of the formation of lead and the mass ratio of uranium to lead found in the rocks, it has been calculated that 200 million years have elapsed since the rocks of the coal age were formed. The lower Precambrian rocks are 1,300 million years old. And these rocks are intrusions in the sedimentary rocks, so that the ocean has a still greater age. By this method of estimation Professor Russell at Princeton has shown that the age of the oldest rocks is at least 2,000 million years. Now if the temperature of the earth in the original gaseous state can be safely estimated, the laws of cooling are sufficiently well established to determine the time required for the gas mass to become liquid. Making reasonable assumptions for the energy content of the earth vapor, figures show that 5,000 years were required for the earth's liquefaction and 10,000 years for its solidification. It is very probable therefore that 15,000 years elapsed before the oceans were condensed and came into being.

In considering the rôle of condensation in the production of heat and light of stars, Eddington at Cambridge has made some calculations on the bright pulsating star delta-Cephei. This interesting star is 700 times brighter than our sun and 60,000 times farther from the earth. It has a mass ten times greater than the sun and a temperature

which varies from 6,000 degrees at the surface to six million degrees at the center. It fluctuates in brightness from a maximum to a minimum in five and one third days. If condensation accounts for the brightness, then the period of pulsation should change by seventeen seconds per year. Observations show, however, that since 1848 the period has been entirely uniform and the change since 1785 has been less than 1/150 of what it should be.

Eddington has pointed out also that in order that the star mass may not collapse under the enormous pressure of the upper layers there must be a large temperature gradient from center to circumference. Either the acquisition of meteoric bodies or the condensation of mass must add energy only to the outside and collapse can not be prevented by feeding the gradient at the wrong end. Eddington concludes therefore that neither hypothesis can account for the energy, although either may contribute a part.

At the present time the physicist knows of only three possible ways by which the heat of the universe can be produced, the breaking down of complex elements as in radioactivity, the building up of more complex elements from simpler ones and the complete transformation of matter into energy. The last of these has been accepted by Jeans and Eddington.

Early studies in radioactivity showed that a mass of radium evolves enough heat every hour to melt its own weight of ice, and twelve hundred years are required for half its mass to transform into its products, radon and helium. But if the enormous heat of the stars is to be explained on the basis of radioactivity then there must be assumed in the stars the presence of elements tremendously more radioactive than any we now know on the earth. It is not at all likely that absolutely every trace of such elements should have been entirely erased from the rock records of the earth's history.

The second of the methods has been suggested by two contemporary lines of research, both of which originated at Cambridge. Through a period of twenty years Sir Ernest Rutherford and his coworkers have shown that gases, nitrogen, oxygen, chlorine, etc., when bombarded by alpha particles, that is, positively charged atoms of helium, have their molecules and atoms broken up. Analysis of the products by a magnetic field reveals the presence of hydrogen from such collisions.

Parallel with these successes Aston has analyzed, also by a magnetic field, the gas atoms which have been disintegrated by the rough treatment received in a low pressure tube which transmits an electrical discharge. From the interpretations of the mass spectra in these experiments we know that the nuclei of the heavier elements are aggregates of the nucleus of hydrogen.

Aston has pointed out that if the atom of oxygen is given the atomic weight 16 then most of the other elements have atomic weights which are very nearly whole numbers. Hydrogen is the noticeable exception which has an atomic weight 1.008. In the formation of helium of atomic weight 4, from hydrogen atoms, there is therefore a loss of mass of .008 or 0.8 of one per cent. of the hydrogen. Calculation shows that if our sun's energy is to be accounted for by the transformation of this matter into energy, and transformations of all other elements can probably be neglected in comparison, then it must be assumed that the whole of the sun was originally hydrogen. If it were so composed, its existence, past and future, can not exceed a hundred billion years. While this just about satisfies the time requirements imposed by other considerations, it is none too liberal. It has been argued that the stars are not hot enough to bring about the formation of helium

from hydrogen. The recent physical experiments compel us to believe, however, that somehow, somewhere this transformation has taken place and where, it has been asked, can one find a hotter place than in the stars.

On the third hypothesis, that of mass transformation, the time scale for the existence of the sun and stars is increased at least a hundred fold. The first evidence of the identity of matter and energy was suggested by the experiments of Sir J. J. Thomson in 1881. He showed that an electric charge in motion possesses inertia or mass due to that charge. Later, in the Kaufmann-Bucherer experiments, it was shown that the mass of an electron is proportional to its velocity, which leads directly to the conclusion that an electric charge at rest has no mass at all and hence matter and electricity in motion are identical. This conclusion is responsible for the frequent statement that all matter is electricity.

It would appear that the foundation for Einstein's hypothesis of identity of matter and energy was experimentally well established. While we have not been able to change matter to energy in any laboratory experiment there is no reason to believe that it does not take place under the conditions of enormous pressure, temperature and density which are found inside the stars. We may never be able to reproduce on earth these unusual conditions and it may be we are denied this privilege for our own protection. We must bear in mind that our world with all the diversity of conditions and life upon it is a most unnatural occurrence in the universe. Sir James Jeans says we should have to visit thousands of millions of stars before finding a planetary system as recent in creation as our own, and we should have to visit millions of millions of stars before finding a planet on which civilization is as recent a growth as that of the earth.

Before leaving the hypothesis of transformation of matter to energy it should be mentioned that there are some difficulties. Eddington, who is perhaps the strongest advocate of the theory, suggests that we should expect the greatest sources of heat to be in the newer stars and especially we should expect it where the gravitational density and temperature are highest. There are, however, so many contradictions and exceptions that no coordination can yet be seen. The theory can be treated only as a working hypothesis, a starting point for investigation.

A new and promising contribution to the whole problem of the origin of energy as well as an escape from the "Wärmetod" are the experiments of Professor Millikan at Pasadena. With zeal and insight which is characteristic of his work, Professor Millikan has for the past six years investigated the causes of the slow discharge of electroscopes which occurred in the earlier experiments of the Canadian physicists, Rutherford and McLennan. It was thought by the earlier observers that the leak of the electroscopes was caused by ionization of surrounding air which in turn could be traced to radioactive elements in the earth's surface. Millikan and his coworkers find that there is coming into the earth's atmosphere from outer space a penetrating radiation of the nature of x-rays or gamma rays. These are the so-called cosmic rays. These rays represent energy ten times as great as the hardest gamma rays of radium. They will penetrate a six-meter wall of lead and discharge the electroscope 70 meters under water. The beam of radiation has been shown to be composed of three principal frequencies. Now, as already stated, the work of Aston shows that the formation of heavy atomic weight elements out of lighter ones involves the loss of matter, and Einstein's theory shows that matter may be transformed into energy. Now

the cosmic ray frequencies coincide almost exactly with the theoretical frequencies derived by assuming the formation of helium and oxygen out of hydrogen and the formation of silicon and iron out of either hydrogen or helium, that is, the percentage loss of mass of hydrogen and helium is just sufficient to yield the observed wave-length when converted to energy, according to the theory.

There is support to this suggested upbuilding of the elements in the fact that the abundant elements in the meteorites, on the earth and in the stars, as revealed by the spectroscope, are just the elements whose formation could give rise to the three principal wave-lengths of the cosmic rays. Even the intensity of the band is greatest just where the Aston formation shows that greatest matter disappears and greatest amount of energy is thereby created. But there is present in the cosmic rays no extremely high frequency corresponding to the high intensity which would be incident to the formation of energy by the annihilation of electrons and protons.

Professor Millikan believes it is possible that waves of energy radiating away from the stars toward the boundaries of space may by some unknown process condense into electrons. There, where there is no pressure and no temperature, these charges may gravitate together to form hydrogen atoms. These in turn, like the molecules in the formation of crystals, may coalesce to form the heavier elements with the release of cosmic rays as a by-product. It is not difficult to imagine that the star dust may condense like water vapor into drops, to form the great star masses. These represent potential energy of mass separation. Thus the picture of the dissipation of energy and its reformation is complete. This inspiring bit of imagination is satisfying because it makes of the energy transformations of the universe a reversible cycle.

Since Einstein has made of the universe a closed system, it is to be expected that the energy transformations should be reversible. This greatest of nature's phenomena would involve a perfect reversible cycle and therefore a nullification of the second law of thermodynamics. It permits for the universe an escape from the "Wärmetod." While we see no way for a limited part of the universe like the earth to escape the "heat death" the universe as a whole may do so. Therefore to speak of the age of the universe has no meaning.

In conclusion, I should like to urge an attitude of liberality and openmindedness. There is much yet to prove, but quite likely the fingerpointing is in the right direction. Fanciful theories will disappear as soon as better ones are offered. We can make no progress in science if we are confronted by the fear of obstacles and criticism lurking around every corner. The century just passed was an age of materialism—perhaps too much materialism. Our scientific structure emerges out of a fantastic assemblage of failures and successes, in theory as well as experiment. No one could have predicted the unparalleled success in stimulating research and in correlating results which has come as a result of the almost reckless assumptions made by Einstein, Bohr, DeBroglie, Compton and the rest. If it be recklessness, I believe we are much farther in our quest for the truth because of the risk these men took.

For thirty years physicists have been engaged in analysis, analysis of radioactive products, of atoms, of protons, of the spectrum and so on. If Jeans and Eddington and Millikan want to work at synthesis and if in their process they overthrow our second law of thermodynamics in order to make of our universe a reversible cycle, who shall dispute their right?

RECENT TRENDS IN GEOGRAPHY

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GEOGRAPHY to the ancients included all studies of the earth and its life. It contrasted with astronomy, mathematics and philosophy. In time most of what the ancients included under geography was studied by specialists in only a portion of the vast field, and gradually became known by special names. Geography, therefore, became the "mother of the sciences."

The movement toward specialization became so great during the 19th century that many people thought that there was nothing left to geography but place geography and commercial geography. At any rate most of what was taught in American schools under the name of geography during the last half of the 19th century were facts as to the location of places, and as to the products exported. Many leaders of to-day, trained during that period or by people so educated, still think of geography thus narrowly, and for that reason it is often attacked by those who do not realize and appreciate its present status.

Geography has suffered, of course, by the loss of many scientific men who specialized and became known not as geographers but as geologists, anthropologists, physiographers, ecologists, climatologists, etc. It lost so much of its former prestige that it was scarcely taught in American universities at the end of the last century, and was not recognized as a distinct science by the National Academy of Sciences, or in Cattell's "American Men of Science."

During recent decades, however, it has won increasing recognition, first in Germany and France, and, especially since the world war, also in Britain and the United States. At present geography is taught in most universities, and there are scores of full professors of geography on the faculties, a number of universities having more than four. It is said that every university in Germany and Great Britain has a chair of geography, and nearly all of the larger American universities have departments of geography. Indeed Harvard and Clark have Schools of Geography. Recently, moreover, a geographer, Isaiah Bowman, director of the American Geographical Society of New York and author of "The New World," was elected to the National Academy of Sciences, the first man elected primarily for his work in human geography.

Geography has won this place because of the realization on the part of leading educators that it cultivates a field of knowledge well worth cultivating and not included in any other.

Geography has become far more than place geography and commercial geography, and now has several additional subdivisions, those of chief importance in universities being three phases of human geography, namely, economic geography, regional geography and historical geography. The study of plant and animal geography is, however, rather generally left to biologists, as there is an increasing tendency to restrict the courses given in departments of geography definitely to how the environment influences the life of people, in other words, to human ecology.

Geography's special field, the influence of the natural environment upon the nature and distribution of man's activities and qualities, places it between the natural and social sciences. As a result of its dual aspect, geography is classified as a social science in most French universities and in such universities as

Michigan, California, Minnesota and Ohio, but, on the other hand, it is classed as a natural science in most German universities and in several important American universities, including Wisconsin, Illinois, Princeton and Cornell. At Chicago, under the new grouping of departments, it is placed in both the social and the natural science groups.

Geography is well represented on the board of the *Social Science Abstracts*, the chairman of that board being a geographer. It is included, however, only incidentally in the great Encyclopedia of the Social Sciences, now being published in several volumes. The failure of sociologists to more generally recognize that geography has a significant contribution to make to the social science discipline is due to the incomplete development as yet of social geography.

Because of the fact that social geography depends not only on other phases of geography, but also upon history, sociology and economics, for much of its factual material, its later development is to be expected. As it gives promise of being of significant social value, it will be worth while to indicate some of its objectives, and something as to its limits.

Social geography is the study of how the environment influences people in considerable groups, not as individuals, families or corporations. It especially considers the variations in social ideals from place to place so far as their distribution is affected by environmental influences. Hence the shifting centers of civilization, and the rise and fall of communities and of nations are subjects of particular interest to the social geographer. Within a country the social geographer endeavors to discover what environmental influences help explain marked sectional differences in educational efficiency, in the production of significant contributions to civilization, in the social health, including criminality, and in the political influence of areas. A special phase is the study of the contrasts in the production of leaders of various kinds.

Social geography includes, therefore, certain parts of the fields of various other subdivisions of geography. Of economic geography, it includes the effects of the resources and their use upon the social life and ideals of the people, but it considers only incidentally, if at all, the phases of economic geography ordinarily studied, namely, the distribution and characteristic of the resources and the conditions affecting their utilization.

Of regional geography, social geography considers, to be sure, the contrasts among the larger regions in respect to topography, soil, climate and resources, but it especially considers the distribution of differences ordinarily ignored by the regional geographer, differences, for example, in the output of leaders, in the death rate, in the ownership of homes, in literacy—in brief, in the social forces of various kinds. Because of the often great local contrasts in conditions of social significance, the social geographer pays attention to even the lesser divisions of cities, towns and country, so far as they display significant contrasts in social ideals. Local differences, for example, in illiteracy, the birth rate, and in criminality are sought for by the social geographer who relates these differences so far as is practicable to geographic differences.

In the domain of historical geography, social geography is little concerned with the topics usually discussed, namely, the effects of the weather or of local topography or soil upon the outcome of a battle, or in the geography of territorial changes made in treaties of peace. Instead, social geography is concerned with the geographic influences that have effected the rise and fall of nations, the survival or elimination of racial types, the changes in ideals which have accompanied the migration of peoples, the spread of language or of politi-

cal influence, and the fuller utilization of resources.

Political geography is mostly a phase of social geography, although the social geographer leaves to the special student of political geography such topics as the details of the location of boundary lines and capitals.

This brief survey indicates the general scope of social geography. Its main objectives are to make full use of all available knowledge of the environment and its influences in order to more fully understand the customs, attitudes, and actions of groups of people.

Its chief methods are three: A study of differences in the customs and attitudes or ideals of originally closely similar peoples who, by reason of migration or of local changes in the environment such as result from the exploitation of previously unused mineral wealth, now have different environments. A second great method is the study of geographic environments that are similar in most respects but are dissimilar in a few, in the effort to find the possible cause of the observed differences in the social structure. The third method is by studying some special social feature, such as the position of women, the conditions of hygiene, or the prevalence of labor disputes in numerous environments to see whether they are correlated with any special environmental condition. For example, the social geographer inquires whether the production of leaders who have more than local and temporary significance is especially associated with any type of climate such as a cool climate with considerable seasonal range, and frequent changes of weather.

With so vast and difficult a field, and with few qualified investigators to work it, little has yet been established. Nevertheless a few generalizations have been deduced. Some of those suggested by Ellsworth Huntington and the present writer may be summarized as illustrations of the problems with which social geography deals.

Hypotheses Advanced by Social Geographers

(1) Civilization advances rapidly only where climatic conditions are at least reasonably favorable. If transported into an unfavorable climate, civilization soon declines unless continually renewed from more fortunate regions. Therefore, if the people of the favored regions wish to maintain a high level of civilization in less favored regions, they must not only supply leaders and wealth in a single campaign, so to speak, but must continue to do so decade after decade.

(2) Democracy is interfered with by exceptionally fertile soil, and by other conditions under which a living may be easily won. In such places the land and other wealth, and hence the power, are normally concentrated in the hands of the few, while the bulk of the population remain in a relatively retarded condition. In somewhat less fertile or productive environments, on the contrary, there is a distinct tendency toward relative equality of wealth, education and power.

(3) Such quickly extracted natural resources as oil, coal, gold, and timber are socially detrimental to the community which extracts them, and are therefore social liabilities, not assets, to such areas.

(4) The utilization of natural resources depends primarily upon the characteristics of the people, especially on their energy and mechanical advancement, rather than upon the proximity of the resources. Most of the coal and oil, for example, are used at considerable distances from the places where found, while, conversely, little local use is made of coal or oil except in areas where other geographic conditions are sufficiently favorable so that the people are economically qualified to use them.

(5) Only a small fraction of the world's area produces any appreciable number of leaders in proportion to population. This is because the effective use

of talent requires an appreciative public, one which actively supports originality. Most of the world's people are hindered by the conditions under which they live from being able to effectively use and support most sorts of talent. Areas within which it is rather hard to make a living may, however, produce numerous leaders if the local social environment is favorable, and if the leaders are in demand in other areas readily reached.

(6) Only a small part of the world now has a good social environment, because in most places one or more of the essential elements is lacking. These elements include a good geographic environment, which among other characteristics has a climate cool enough and variable enough to stimulate mental activity, but with sufficient warmth and moisture to permit profitable agriculture. A good social and biologic heredity is also required, as are facilities for the exchange of ideas.

(7) Cities contain a much wider diversity of people and activities than do larger areas of comparable population not adjacent to cities. This is because cities afford more opportunities for people of diverse abilities to obtain a living.

(8) The contrasts in social ideals within a city or other limited area are often enormous. In general they correspond with the popular idea of the desirability of the district. Slight differences in elevation, effectiveness of transportation facilities, physiographic attractiveness, or leadership are often accompanied by marked differences in social ideals. This arises largely through a process of social selection whereby people of various types sort themselves out as residents of different geographic areas.

(9) In order fully to appreciate social attitudes, the effects of selection as well as of geographic environment must be adequately considered. As mobility increases, selection operates increasingly powerfully, leading to sharper and sharper contrasts among the local populations and hence in their ideals. For example, in an area where the population is growing rapidly by the inflow of people, the averages of enthusiasm, optimism, mental alertness and physical vigor are high. Correspondingly, commercial ability is exceptionally represented in commercial cities, intellectual activity in educational centers, and pessimism in places losing rank in population and influence, such as declining farming districts.

(10) Even the areas that are best for civilization in one or more respects, such as climate, suitability for diverse agriculture, industrial activity, and the exchange of goods and ideas, nevertheless lack considerable of being ideal, because perfection does not exist anywhere on the earth. Hence each area needs to be extensively supplemented from other areas. Any agency which facilitates a ready exchange of goods and ideas is fundamentally socially advantageous. Consequently it is extremely doubtful whether tariffs and taxes on the means of transportation and communication do as much good as harm.

It will be readily conceded that such working hypotheses as the foregoing are distinctly thought-provoking and hence highly educational to those prepared to consider them. If social geography effectively accumulates data by which such hypotheses as these are tested, it is a field of great social significance and merits encouragement, and increased study in our universities. If by accumulating data indicating their correctness, it can cause influential people to take due account of even a few such generalizations, it will exert a profound influence.

PROHIBITION AND THE STRAW BALLOT

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THIS is a presidential year. Astute political observers say that, more so than in any election for forty or fifty years, the outcome will depend upon policies rather than personalities. And among the policies that interest vitally the American electorate at the present time, prohibition stands in the front, possibly only second to the more obviously economic issues. It is of more than ordinary importance, therefore, to gauge the sentiment of the country concerning the continuance or the abandonment of prohibition as embodied in the eighteenth amendment to the Federal Constitution.

Attempts to gauge this sentiment by noting the fortunes of candidates to political offices who have announced publicly their stand with reference to prohibition confuse more than they enlighten, because of the inconsistencies revealed. A complete solution can be obtained only by referring the amendment again to the people, preferably to state conventions elected for that purpose. It is to be hoped that this method will ultimately be applied, and it appears not unlikely that it will be applied in the near future. But until then other means of obtaining the desired information must be used.

For this purpose the straw ballot has been resorted to by many agencies and with varied success, and, incidentally, with varying results, depending mainly upon the section of the country covered, or the class of people whose opinions have been canvassed. The most ambitious of these straw ballots and the most widely discussed have been the two polls sponsored by the *Literary Digest,* one in the spring of 1930 and one in the early months of the present year. In each case more than twenty million ballots were sent to all sections of the country, each state being circularized somewhat closely in proportion to its voting strength. And in each case less than twenty-five per cent. of the ballots mailed out were returned.

The general public interest in prohibition and the great political import being attached to the returns of the *Literary Digest* polls warrant a most complete analysis of the returns, and a much more searching criticism of their significance than has hitherto been accorded them. Discussions of the two polls have been concerned entirely with the face value of the returns, with no apparent suspicion that these may not truly represent the sentiment of the twenty million people to whom ballots were mailed. The limitations of the returns rest in the inherent weaknesses of the straw ballot.

The agencies sponsoring a straw ballot can contribute to its success only to a limited extent. They can circularize a large number of people. They can compile their mailing lists from people of all classes and occupations, residing in all parts of the country. They can apportion their ballots among these classes, occupations and sections somewhat in proportion to their voting strength. But when this is done, the game passes out of their hands. The extent to which the different classes, occupations and sections will respond is entirely beyond their control. In particular the extent to which those favoring one or the other side of the question at issue will respond is out of their hands entirely. The representative character of the returns with respect to the different classes and occupations of people and the different sections of the country can be judged if the

ballots are marked with this information. But the extent to which the "pros" and the "antis" have accepted the invitation to express their opinions can not be judged from any superficial examination of the returns, and yet the accurate interpretation of the returns will depend directly upon this point. If the incentive to vote is as strong for those of one opinion as for those of another, the poll can be interpreted at its face value, but if this is not the case, the returns may give a greatly distorted picture of popular sentiment.

The incentive to vote in such an amiable contest as a straw ballot, where no political issue is at stake, will depend upon the questions asked. If it is a presidential poll, there is no apparent reason why, under normal conditions, the urge to vote among the supporters of one candidate should be any different than that among the supporters of his opponent. The fact that such polls have predicted accurately the outcome of a subsequent presidential election indicates that the straw vote was in fact unbiassed and that the followers of the two candidates must have voted to very nearly the same extent.

But in a prohibition poll, under prevailing conditions at least, the situation seems quite different. Those favoring the *status quo* may very well feel complacent, with little inclination to express themselves in a ballot in which the *status quo* is not threatened or endangered. On the other hand, those dissatisfied with the Eighteenth Amendment are apparently laboring either under a feeling of personal injury, or under a conviction that by reason of this amendment the government is unwarrantably infringing on the personal liberty of its citizens; or they may be inspired by a horror of the official venality seemingly associated with prohibition enforcement, a horror of the apparently wide-spread evasion of it and a horror of the vice and crime it may appear to foster. These feelings surely are more articulate than a feeling of complacency and may well constitute a greater incentive to vote.

The question of biassed returns in a straw ballot occasioned by a difference in the incentive to vote among the "ayes" and the "nays" can be pursued beyond the stage of mere speculation. It can be settled definitely by comparing the proportions of ballots marked in favor of the proposition proposed, obtained from the different states, with the proportions of the ballots mailed out that have been returned. If those states favoring the proposition the most strongly are returning greater percentages of the mailed ballots than those states favoring it less strongly or opposing it, this is *prima facie* evidence of a biassed return, since the percentage of ballots returned in any state is a measure of the average incentive to vote in that locality.

In applying this principle to the prohibition poll of 1930, it should be remembered that three propositions were proposed, any one of which could be favored. A recipient of the ballot could vote for (1) repeal of the eighteenth amendment, (2) its continued enforcement, or (3) its modification to permit the sale of light wines and beers. Of the approximately five million ballots returned, 40.43 per cent. favored repeal, 30.46 per cent. favored enforcement, and 29.11 per cent. favored modification.

To test the existence of bias in the returns, the five million ballots have been divided into five groups, each containing approximately a million votes. The first group comprises the total returns from the six states showing the strongest expressed sentiment for repeal. The second group comprises the total returns of seven states ranking next in "wet" sentiment as just defined. The third group comprises the returns of nine states next in order, and the fourth and fifth groups comprise the returns from

twelve and fifteen states, respectively. The nature of the composite returns from these five groups of states is indicated by the average figures listed in Table 1.

It seems clear from this presentation of the returns that those localities furnishing a high percentage of "repeal" ballots also returned a high percentage of the ballots mailed to them, and *vice versa*. A graphic demonstration of this fact is given in Fig. 1. On the other hand, the higher the percentage of "enforcement" ballots among those returned, the lower the percentage of ballots returned from those mailed out. No apparent relation exists between the percentage of "modification" ballots and the percentage of ballots returned. These voters' ballots made up a fairly constant proportion of the returns from each group of states, averaging 29.1 per cent. A distinctly biassed return in the poll is thus evident, due to a much greater incentive to vote among those favoring repeal than among those favoring enforcement.

Now let us examine the picture of the returns given in Table 1. It seems evident that the circles representing the five groups of states are not scattered at random over the chart, but rather tend to arrange themselves, somewhat crudely it is true, along a curve. It is possible to determine the type of curve if one makes certain assumptions that seem reasonable from the returns themselves. These assumptions are, first, that except for local influences differing from state to state, the "wets" and "drys" were voting in certain fairly constant average proportions, the proportion of "wets" voting evidently being much greater than the proportion of "drys." The second assumption is that the "modificationists" are a mixed group, made up of a "wet" and a "dry" wing, and that the proportion of "moderate wets" and "moderate drys" in the modification group in different localities varies as the proportion of "wets" (for repeal) and "drys" (for enforcement) in those localities varies. Hence, the "modificationists" would vote in a proportion equal to the weighted average of the proportions in which the "wets" and "drys" of their respective localities are voting.

These assumptions, put into mathematical clothing, define the type of curve which the circles in Fig. 1 are attempting to follow. The curve is a hyperbola, but since there are many different kinds of hyperbolas, the particular kind that describes the returns of this poll must be determined from the returns themselves by a process of "fitting." When a man goes to the tailor for a suit of clothes to be made to order, he picks out the pattern or style first, but then the

TABLE 1

THE RETURNS FROM THE LITERARY DIGEST PROHIBITION POLL OF 1930, GROUPED IN CLASSES OF ABOUT A MILLION VOTES, ACCORDING TO THE INDICATED SENTIMENT FOR REPEAL

Number of states grouped	Number of ballots returned	Per cent. of mailed ballots returned	Distribution of returned ballots		
			Per cent. for repeal	Per cent. for enforcement	Per cent. for modification
6	997,040	30.42	49.84	19.17	30.99
7	948,363	29.02	46.60	27.47	25.93
9	1,002,024	21.93	42.68	28.98	28.34
12	1,000,110	21.49	34.11	33.13	32.76
15	810,756	18.18	26.47	45.62	27.91

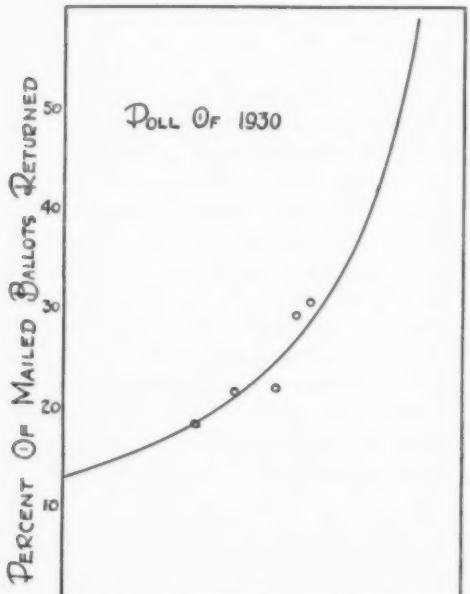

FIG. 1. EQUATION OF PREDICTION CURVE—

$$y = \frac{544.7}{41.90 - .461x}$$

y = per cent. of mailed ballots returned.
x = per cent. of returned ballots for repeal.

tailor must fit the pattern to his customer's own peculiar dimensions. Using this analogy, the pattern is a hyperbola and the tailoring consists in adapting the pattern to the situation at hand, though a mathematical pattern is much less flexible than a tailor's pattern, so that a perfect fit is only rarely obtained. The tailored curve is shown in Fig. 1; the fit is not a bad one.

We may now disregard the circles in the chart and reason from the curve, which tells us more clearly what the returns are trying to express. We see that when there are no ballots marked for repeal, the return of mailed ballots is only 13.0 per cent. This measures the extent to which the "drys" are voting. When no ballots are marked for enforcement, then 70.9 per cent. will be marked for repeal, the remaining 29.1 per cent. of returned ballots being marked for modification. The curve shows us that if 70.9 per cent. of the returned ballots are marked for repeal, 59.1 per cent. of all ballots mailed will be returned. This means that 59.1 per cent. of the "wets" are voting. The "modificationists," according to our premises, voted to varying degrees depending upon prevailing "wet" and "dry" sentiment in their localities. By an indirect calculation it appears that, on an average, they returned 22.6 per cent. of the ballots mailed to them.

If the "wets" voted to the extent of 59.1 per cent., the "drys" to the extent of 13.0 per cent., and the modificationists to the extent of 22.6 per cent., then the vote of the 20 million persons to whom ballots were sent, if they had all voted, can be readily predicted from the total numbers of ballots marked in the three ways. For the entire country it appears that only 16 per cent. of the 20 millions favored repeal, about 55 per cent. favored enforcement and about 29 per cent. occupied an intermediate ground.

The wide discrepancy between this prediction and the returns actually received represents the bias inflicted on the poll by the very nature of the questions asked. It illustrates the uncertainties of straw ballots, no matter how extensive they may be nor how fairly they are conducted and the returns compiled. When only a small fraction of the ballots mailed out are returned, the face value of the returns may be high, or they may be greatly misleading, as in the present case. Only a statistical analysis of them can tell whether they are of the first description or of the second.

In the second *Literary Digest* prohibition poll, just completed, the recipients of the mailed ballots were asked to express themselves on one proposition only, namely, whether or not they fa-

vored repeal of the eighteenth amendment. Again more than twenty million ballots were mailed out, of which less than five million were returned, a return of only 22.39 per cent. Of the returned ballots, 73.67 per cent. were marked for repeal and 26.33 per cent. were marked for continued enforcement. On their face the returns indicate an overwhelming sentiment for repeal, a proportion of about 3 to 1.

But before accepting this superficial verdict, it would be well to examine the returns for the same type of bias so evident in the returns of the preceding poll. If one compares for each state the percentage of returned ballots marked for repeal with the percentage of mailed ballots returned, no close correlation is evident. The irregularities are too great. However, one may divide the states into two classes, one class offering evidence of biassed returns and the other class offering no such evidence. The first class would include those states returning more than 22.39 per cent. of the ballots mailed to them and marking more than 73.67 per cent. of the returned ballots for repeal, as well as those states returning less than 22.39 per cent. of the mailed ballots and marking less than 73.67 per cent. of the returned ballots for repeal. The second class would include all states not falling under the two categories of class one. When such a division of states is made from computations based upon the published returns of the poll, it is found that thirty states offer evidence of bias, while nineteen do not.

For purposes of mathematical analysis, the returns have been divided into eight classes, depending upon the percentage of returned ballots marked for repeal. The first class includes all states for which 85 per cent. or more of the returned ballots favored repeal of the prohibition amendment. The next class includes all states for which from 80 to 85 per cent. of the ballots returned were marked for repeal. Succeeding classes are similarly defined, each class including a range of 5 in the percentage of "wet" ballots, except the last, which includes all states for which 55 per cent. or less of the returned ballots were recorded against prohibition. The relation between the percentage of mailed ballots returned and the percentage of returned ballots marked for repeal for the eight groups of states is pictured in Fig. 2. While much irregularity is evident, it appears that there is a distinct tendency for a high percentage of wet sentiment to be associated with a more complete return of mailed ballots and *vice versa*. This means a greater incentive to vote among the anti-prohibitionists than among the prohibitionists, a conclusion also deducible from the returns of the first poll.

In Fig. 2, we must again attempt to fit a curve to the circles representing the returns of the poll, but it is evident that a good fit can not be expected because of the irregularities evident. It is like the job a tailor would have in fitting a modish pattern for a suit of clothes to the hunchback of Notre Dame. The hyperbola pattern will not bend itself around the irregularities. The fitted curve shows, however, the same

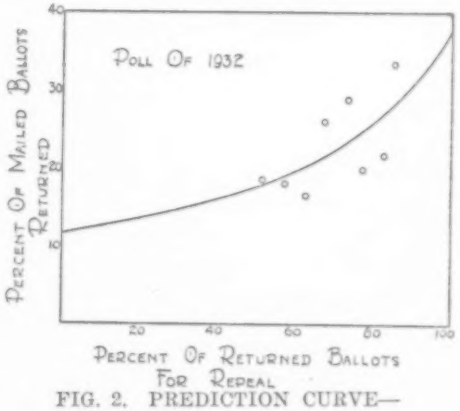

FIG. 2. PREDICTION CURVE—

$$y = \frac{434.7}{37.70 - .262x}$$

y = per cent. of mailed ballots returned.
x = per cent. of returned ballots for repeal.

downward swing from right to left as do the actual returns, and it threads its way through the circles in a manner indicating as close an agreement between fact and theory as could be expected. The curve predicts that, among those favoring repeal, 37.7 per cent. returned the ballots mailed to them, while among those opposed to repeal only 11.5 per cent. marked and returned their ballots. These values, together with the numbers of returned ballots marked in the two ways, lead to the conclusion that only 46 per cent. of the twenty million people to whom ballots were sent favored repeal of the eighteenth amendment, instead of 73.7 per cent., as indicated on the face value of the returns.

In summarizing this analysis of the two prohibition polls, it is interesting to inquire to what extent they are consistent and to what extent they indicate a shift in sentiment on the question. It is significant that the estimated incentive to vote among those favoring enforcement of the amendment in the first poll and among those opposing repeal of the amendment in the second poll is very nearly the same, as measured by the estimated percentage return of their ballots, namely, 13.0 as against 11.5. This agreement would indicate that the complection of this group has not changed. On the other hand, the incentive to vote among those favoring repeal was much greater in the first poll than in the second, as measured by an estimated return of 59.1 per cent. of mailed ballots against 37.7 per cent. The complection of this group has evidently changed in such a way that the incentive to vote has been greatly reduced. In the first poll there was a third group of dissenters, favoring modification of the eighteenth amendment to permit the sale of light wines and beers. How did this group vote in the second poll? If their disagreement with prohibition became more intense in the two-year interim, or if, merely because they were denied the privilege of expressing their more moderate views, they preferred repeal rather than continuance of a condition with which they were dissatisfied, they would align themselves with those who all along had intensely favored doing away with prohibition entirely. Being less intense in their dissatisfaction, however, their incentive to vote would be less and their amalgamation with the "repealers" would lower the average percentage of mailed ballots returned for this group in the second poll, somewhat as the percentage actually was lowered from 59.1 to 37.7.[1] That such a regrouping actually occurred, perhaps with no marked change in sentiment toward prohibition, receives some confirmation from the fact that in the first poll, 55 per cent. of all people canvassed appeared to favor continued enforcement, while in the second poll 54 per cent. of all people canvassed were against repeal. Again this group seems a stable one. The 16 per cent. of outright "repealers" and the 29 per cent. of modificationists in the first poll apparently combined forces in the second poll.

The present situation appears to be this, if one may assume that the twenty million people on the mailing lists represent the entire country. Approximately half of the population are steadfastly opposed to repeal of the eighteenth amendment, while approximately half favor repeal if no other course is open. A minority of the latter half are steadfastly in favor of repeal, while a clear majority would probably be satisfied, either with a modification of the amendment to permit the sale of the less intoxicating liquors, or with a modification of the enforcement laws leading to essentially the same result.

[1] In fact, if the voting percentages of the "repealers," 59.1, and of the "modificationists," 22.6, in the first poll are weighted by the relative strengths of these groups, 16 and 29 respectively, and averaged, the result is 35.6, not greatly different from 37.7, the voting percentage of "repealers" in the second poll.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

ELECTRICITY, THE MODERN HANDMAID OF CHEMISTRY

By Dr. COLIN G. FINK

HEAD, DIVISION OF ELECTROCHEMISTRY, COLUMBIA UNIVERSITY

THE science and art of chemistry had its beginnings many thousand years ago. Thus, such chemical products as soap, glass, paper and porcelain were known to the ancients, and the knowledge of manufacturing these and other products was handed down from generation to generation. Who was the inventor of soap—one of the most important of chemical products? His name and origin have long since been forgotten. Through the ages up to as recently as 1800, there were but slight changes in process of manufacture of soap and many other chemical products. New and valuable articles were added from time to time, but the basic methods of preparation and manufacture remained inherently the same. With the close of the eighteenth century, however, the classical discoveries of Galvani and of Volta opened to the chemist an entirely new field of attack. Chemical products could be made or decomposed by electricity. The epoch-making discoveries of Galvani and Volta in Italy stimulated research throughout Europe, and within a few years Michael Faraday, of England, announced to the world his discoveries of the intimate interrelation between electrical and chemical phenomena. By the middle of the nineteenth century the comparatively limited supply of electricity from the Volta battery was infinitely increased through the invention and perfection of the electric dynamo—a machine that converted readily available, mechanical power into electrical energy.

After the appearance of the electric dynamo, the greatest forward step in chemistry and chemical manufacture took place: not only were old processes —cumbersome and costly—discarded, and new, electrical, clean and simple processes substituted therefor, but a host of new products were discovered. New metals, such as sodium, magnesium and aluminum, never before known to man, were extracted with the aid of electricity from familiar salts. Chlorine gas, which is the underlying basis of our bleaching industry, was formerly made by a very lengthy and wasteful chemical process. Now, by merely passing an electric current through water in which ordinary table salt is dissolved, tons of this yellowish-green gas are produced, and so easily and cheaply that the industry is forever turning out more chlorine than is consumed by the public. And this very electrical, or electrochemical, process, which produces chlorine gas at one pole, produces caustic or lye at the other pole, simultaneously. This caustic or lye is mixed with animal fats and made into soap.

In 1892, Thomas Willson, an American, mixed ordinary marble with coal and passed a strong electric current through the mixture. He obtained a new "stone" or compound, calcium carbide. Returning from lunch on the day of his discovery, it started to rain, and the rain-drops coming in contact with his new product caused a hissing sound and a powerful gas—acetylene—was evolved. This day marked the birth of

one of the foremost of chemical industries—calcium carbide, acetylene, hydrocyanic gas, acetone, acetic acid, solvents, etc.

In 1891, Edward Goodrich Acheson, one of our foremost pioneers in electrochemistry, passed electricity through coal and converted it into graphite—a most valuable lubricant—better and purer than any natural graphite theretofore produced. No lubricant other than Acheson graphite will stand the temperatures developed in our modern super-high-speed bearings. In another experiment Dr. Acheson powdered ordinary coal and mixed it with Coney Island sand, adding a little salt as seasoning. He then sent a powerful current of electricity through this mixture —so powerful that the sand was changed into gas—and the result of the experiment was a new product—carborundum—which you use to sharpen your carving knife or your razor blade.

Many of the chemical plants at this time were expanding, and new ones were being erected in different parts of the country. From the smoke-stacks of these factories thick fumes and often acids belched forth which ruined trees and other vegetation, not to mention the discomforts brought upon people working or living in the vicinity of these factories. F. G. Cottrell suspended a chain through the center of these smoke-stacks, applied a high voltage current and lo, and behold, no fume, no dust any longer came out of the stacks, just as though the factories had shut down completely. But, of course, they had not. Electricity was causing those myriads of smoke and fume particles to go down instead of up. And more than this: the dust was collected and in many cases was found to contain valuable constituents, such as silver. This Cottrell process is so simple that many factories, such as fertilizer factories, instead of avoiding smoke, find it to their advantage to first convert their products into fume or smoke and then pass electricity through the smoke and throw down or precipitate the fine particles subsequently converted into high-grade baking powder and other products.

The ancients knew how to apply gold coatings to baser metals, such as bronze and copper, but the process was tedious and uncertain. The gold had to be first hammered or beaten out into very thin sheets, a process that often took several days to complete. The sheet or gold leaf obtained usually had many holes and other imperfections. This leaf was then mechanically fastened to the surface of the bronze or copper and the bond or union was never very secure, so that the slightest knock or scratch would loosen the leaf. To-day the article, such as jewelry made of base metals, is suspended into water containing a little gold dissolved in it. Electricity is passed through the water, and almost instantly the brooch or ring or other article is completely covered with a resplendent coat of our most noble metal, gold. The coating is uniform and thoroughly adherent. And gold is not the only metal that is now plated over other metals by electricity. Silver, nickel, zinc, lead, copper, tin and chromium are similarly plated to-day. Without electricity your car would have no chromium plate.

Iron is one of the oldest and most serviceable of metals. Yet nearly everything that was ever made of iron by our forefathers has long since turned to rust and disappeared. Only a few rare specimens have been preserved and handed down to us. It is this tendency for iron and steel to rust that has for years stimulated investigations in all civilized countries of the world, with the hope of making iron and steel rust-proof. Here, again, electricity has been the immediate means toward a solution of the problem. By mixing iron with

other metals, notably chromium, and passing powerful electric currents through these mixtures, iron alloys have been produced, such as stainless steel and the chromium-nickel alloy that covers the Chrysler Building, which defy rust and deterioration for all time to come.

Many more examples fully as startling as those cited could be recorded and suggestions might be offered as to electrochemical discoveries and inventions of the future. To mention but a few, we need new products and processes to convert our super-heavy railway equipment into such that will excel that of the modern airplane. We need a chemical machine that will convert the boundless energy of the sun—most of which is wasted to-day—directly into electricity, instead of first converting a mere fraction of sun energy into trees and trees into coal, and coal into heat and heat into steam and steam into electricity. We want to apply electricity to different substances and change these substances easily and rapidly into a food as valuable as milk and as cheap and abundant as spring-water. We want to produce by electrical and chemical means materials harder than diamond and much cheaper than gems, to produce metals lighter than aluminum and stronger than steel, electric lamps ten times as efficient as the best tungsten lamp of to-day, to produce dyes that never fade, and silver that does not tarnish. The investigator in chemistry to-day is indeed fortunate to be able to apply electrical methods in seeking a solution of these and many other important problems.

SCIENCE IN FOOD PRODUCTION

By Dr. RAYMOND A. PEARSON

PRESIDENT OF THE UNIVERSITY OF MARYLAND AND CHAIRMAN OF THE EXECUTIVE COMMITTEE OF THE ASSOCIATION OF LAND GRANT COLLEGES AND UNIVERSITIES

It has been said that the science of yesterday is the commonplace of to-day. We need only to look about us to realize the truth of this saying. Good roads are being laid in every part of our country by thousands of men who know how to do the mechanical work, but seldom do they or the rest of us who use the roads stop to think about the scientific studies that made these roads possible. Electric lights are almost universal in thickly populated communities, and they are becoming common in rural districts. Almost every one knows something about the use of electricity, but seldom do we think of the years of investigation that were necessary to make it available. I might enumerate many other such examples, but they will occur to you. Most of us realize how important are the results of scientific research and we are glad to see this kind of work promoted.

To-day we are to talk about the results of research in food production or agriculture. Science has been finding its way rapidly into this great field of work, and now it can be said that every important agricultural operation is dependent upon or is closely related to certain definite scientific studies that have been completed or are in progress.

A few years ago soil hunger manifested itself, and the yield and quality of crops suffered accordingly. Some soils were wearing out. That problem was finally mastered, temporarily at least, by new knowledge of plant foods which was made available by scientific studies. Now every good farmer knows

how to take care of soil hunger by the proper selection of his crops and by cultivation and by the use of fertilizers. Unfortunately, that problem hardly had been solved before we realized that another soil problem, soil erosion, is just as serious or worse. Literally millions of tons of our best producing soils, which required thousands of years to build, are being carried away by the rivers to the sea. Thousands of acres of good land have vanished. Areas that have been highly productive are now useless. With an increasing population and a larger demand for food, it is evident that something must be done. When the soil was not plowed and cultivated, there was comparatively little erosion, but plowing and cultivating are necessities of civilization. The soil scientists are studying this problem and are making progress.

About 30 years ago the cattle raisers in certain sections of the country were suffering enormous losses from a disease that affected a large proportion of their animals. It was transmitted easily and occurred year after year, in spite of well-known preventive measures. The losses mounted into the hundreds of millions of dollars. Finally a few veterinary surgeons and bacteriologists discovered that the cattle tick was the carrier. With this definite information, and assistance from the zoologists, the disease is being rapidly eradicated. Hog cholera almost threatened to destroy the hog-raising industry until scientific studies showed how it can be avoided or controlled by sanitation and the use of serum.

Years ago it was comparatively easy to raise potatoes. Then, from somewhere, the potato bugs arrived. They killed millions of potato plants and ruined many a farmer's potato crop. The entomologists found methods of controlling these pests, but now we have another potato affliction—the potato blight. Scientific men have told us how to deal with that, too. Successful potato growers have to understand many problems of this kind. And the same is true of producers of other farm products, both in the animal and plant kingdoms.

Questions relating to food production are national questions. They interest everybody, because everybody must eat. And so the Federal Government years ago provided for an agricultural experiment station in every state, in connection with the agricultural colleges. Most of these stations now receive from their own states larger appropriations than from the Federal Government. Also, the Federal Government has provided for research work in the Department of Agriculture at Washington. So there is a great organization of workers in agricultural science. Their relation to the farmers of the country is the same as the relation of scientific men, maintained by big industrial organizations, to those industries. Of course, the public pays for the industrial research indirectly. It pays directly for agricultural research through taxes and appropriations. This is because every person is concerned and because agriculture has no enormous commercial units representing hundreds of millions of dollars that can afford to maintain expensive scientific studies.

There is one important difference between science in its relation to food production and in its relation to most manufacturing operations. Agriculture has more surprise problems, and often these threaten whole crops or herds so they must be dealt with promptly and vigorously. I suspect that manufacturing industries do not require nearly as much emergency research as does agriculture.

It costs about $18,000,000 a year to maintain the state experiment stations, but only about $13,500,000 of this comes from the taxpayers, and about $17,000,000 a year to maintain the research work in the Federal Department

of Agriculture. About 1,800 people give full time to the work in the state stations and a larger number give part time, and there are about 4,000 people in the federal agricultural research work. This may sound like a costly luxury. But, let me say quickly that in comparison with what we spend for food, these expenditures to safeguard the nation's food supply are exceedingly small and even trifling.

I wish there were time to tell you about more of the notable achievements of workers in agricultural science and of the direct importance of all this to every citizen. I can mention only one or two. Some recent discoveries are still novel and therefore interesting to the majority of people. For example, the Japanese beetle has appeared in this country in recent years. When it once gets into a locality, it increases in number with amazing rapidity. It has an enormous appetite for growing plants of many kinds. Various methods of controlling this pest are being studied, but one is unique. Scientific men discovered that this particular beetle is attracted by an odor somewhat like that of the rose geranium, so they developed in the laboratory a substance that has this odor and they are using it as bait for traps to catch the beetles. The geranium aroma is carried by the breezes over a wide area. The beetles in this area fly towards the trap, hoping to get a good meal. They are captured by the gallon and sometimes by the bushel. About 600 barrels, not bushels, of Japanese beetles have been caught this year in a heavily infested area in one of the Eastern states. Think of the food crops they would have destroyed! Let us hope that the entomologists some day will find a bait that will rid the country of mosquitoes! Of course, we know that much has been done already in controlling them by putting oil on the marshes and ponds where they breed. But I have been in places where I thought there must be a few gallons of adult, hungry mosquitoes that ought to be caught for the benefit of suffering humanity.

I would not have you understand that all these scientific discoveries are made by experts, for they are not. Many of them are credited to farmers who had the faculty of observing unusual conditions and of putting two and two together. For example, there was the farmer in France, who, like every other grape-grower, had become familiar with Bordeaux mixture as a remedy to protect grapes. This French farmer noticed that when the spray fell on a mustard weed, it killed that weed, although it seemed to have no effect on other kinds of plants. A spray to kill a troublesome weed was a new idea, but now it has become fairly common for mustard. Sprays for other weeds are being developed by research workers. I wonder if the time will come when weeds will have their numbers and druggists will have the remedies under corresponding numbers, so that anybody can get rid of any weed with the aid of a prescription that he can write himself, such as remedy No. 113 for weed No. 113. Such an achievement may be no more impossible than many of the developments in science appeared a short time before their accomplishment. How happy the hay fever victim would be if some such remedy as I have mentioned could be applied to ragweed! Probably it will come, in time.

Let me emphasize that it is the public —all the people—who are the chief beneficiaries from scientific studies relating to food. The benefits come, to be sure, through the efforts of farmers who apply the knowledge. It may seem remarkable, but it is true, that farmers do not possess trade secrets, and they do not amass fortunes by taking advantage

of scientific work to reduce their cost of production or to protect their crops and animals from destruction. They pass on the advantage to the consumers. If wheat growers could be shown how to cut the production cost of wheat five cents a bushel, then the consumers would get their wheat that much cheaper. Farmers may have their faults. Who does not? But they never have been accused of hoarding, nor of monopolizing. Those practices are not possible in American agriculture.

Summarizing, then, in closing: Research in agriculture is necessary, not only to improve standard agricultural methods but especially to enable farmers to contend with new diseases and pests that have a way of appearing unexpectedly and that may become highly destructive to our food supply. Because of the wide interest in agricultural problems and the dependence of everybody upon their successful solution, the Federal and State Governments have seen fit to support research work. And lastly, the benefits which come from the application of science to food production are passed along promptly to the ultimate consumers.

THE MEDICAL CARE OF ANIMALS IN THE ZOO

By Dr. W. REID BLAIR

DIRECTOR AND GENERAL CURATOR, NEW YORK ZOOLOGICAL PARK

In order to maintain a large collection of wild animals in a state of good health it is necessary to provide suitable sanitary buildings, a wholesome and hygienic food supply and expert medical supervision. In order to successfully combat diseases, especially those of a contagious nature, a most complete and efficient quarantine system is absolutely necessary. A grave form of disease may be introduced by apparently mild or trivial cases. With animals arriving almost daily from different parts of the globe, great care must be constantly exercised in guarding against the introduction of a possibly diseased animal into a collection known to be healthy.

Prevention of disease is the constant aim of the medical department. All sanitary measures contribute to the healthfulness of our animal collections. Disinfection as a preventive of disease plays no insignificant part in the medical work of the Zoological Park. Among the Zoo's charges are some of the rarest and most valuable specimens in the world, and it goes without saying that the death of any one of them would be a great blow to the scientific world, not to mention the serious financial loss entailed, even if it were possible to replace them.

In a zoological park with collections as large as ours, sickness, accidents and death must inevitably occur. Animals are subject to almost as many of the ordinary ills as is man, and in captivity these ills are frequently intensified. The difficulty in arriving at a true diagnosis is greater in wild animals than in the domestic species. Where docility is a pronounced factor, one arrives at a diagnosis by a process of elimination, by the use of the thermometer, the pulse, tapping and listening to the chest cavity, and otherwise handling the patient without undue excitement. While the human patient can tell you his feelings in their regular order we can only infer most of these in the animal through external manifestation of pain and dis-

comfort. The wild animal physician must carefully watch for and accurately observe all such symptoms, and then endeavor to rightly interpret them.

If, in addition to all the obstacles in the way of treating these patients, it is realized that wild animals in captivity are subject to nearly all the diseases common to man and the domestic animals, and that every wild animal is well equipped with claws, horns, sharp teeth or tusks, and with a strength and agility far beyond that of a human being, you may get some idea of the difficulties with which the wild animal physician must contend.

One advantage the animal doctor has over the human practitioner is that he does not have to listen to long tales of imaginary ailments from his patients, nor do they just fill themselves up with patent medicines before coming to the doctor as a last resort. Unfortunately, the "patent medicine man" has not yet appeared with a panacea for all ailments to which wild animals are heir.

When an animal is ill it is, if practicable, removed from its fellows, whether its disease is contagious or not. In the former case the reason is obvious, but in all cases quietness and extra comfort are needed. The patient can be better observed, the symptoms more closely noted, and the disease from which it suffers more clearly defined when the animal is alone and left to the exercise of its own undisturbed will.

To provide for the treatment of diseases and for the operations which are necessary where a large number of animals are kept in captivity, it is essential that hospital accommodations be provided. The New York Zoological Park has a well-equipped hospital. There is probably no other hospital where such a varied list of patients might be seen. The hospital is conveniently located near the center of the park and well isolated within a walled enclosure, which insures quiet. It is a large, single-story brick building, containing medical and surgical wards, operating room, pharmacy, diet kitchen, quarantine room, research laboratory and the doctor's office and study. All the wards are equipped with sanitary cages. Electric exhaust fans, which can be regulated to insure a perfect system of heating and ventilation, are installed here.

In giving medicine to wild animals it is necessary to concentrate the drugs as much as possible. It is best that the animal should not know that it is getting medicine at all, so that it becomes necessary to disguise the drug in some way. For the practitioner of human medicine modern pharmacy has provided a large number of preparations, which in some respects are even more necessary to the animal physician who ministers to sick animals which can not understand the object of what must seem to them ill usage.

Again, there is every reason why the animals should get their medicine in the way that will cause the least disturbance to their feelings and without that excitement which may follow a struggle to give medicines. Small pills, gelatine or sugar-coated, sweet lozenges, tablets or capsules, carefully concealed in an innocent-looking banana, may be administered to an unsuspecting ape, without the slightest difficulty. Occasionally, however, he may suspect, and great is your dismay at seeing him minutely pick the banana apart, find the offending pill, test it with his teeth, smell of it, and finally with a wry face cast it through the bars of his cage at his keeper.

The nursing of sick animals is of the greatest importance. The essentials are pure air, sunlight, cleanliness, warmth and nourishing and sustaining diet. During convalescence all kinds of delicacies are offered to tempt the appetite, first one thing and then another; but no

food is allowed to remain long before the animal, because the very fact of its being constantly present will cause him to loathe it. When the animal has no appetite it may indicate that the stomach is not in a proper condition to digest food; consequently, if forced upon him it will cause indigestion and aggravate the case.

While digestive and pulmonary diseases are the more common ailments requiring medical attention, yet the doctor is frequently called upon to perform major and minor surgical operations. If the operation is painful, a general anesthetic is administered, because in addition to the humane sentiment involved perfect control of the animal is necessary for the safety of the operators and also for the successful handling of the patient. Chloroform and ether are used for general anesthesia, with local injections of cocaine or morphine in minor operations.

Some of the surgical operations that are performed from time to time are unique. Once our African rhinoceros, "Victoria," required a surgical operation for a deep-seated abscess which affected the lower jaw-bone. The rhinoceros was hobbled with ropes, cast upon a grass mattress and put to sleep with chloroform. While less than an ounce of chloroform will send a human being to sleep, it took two pounds of chloroform and three quarters of a pound of ether to put this animal in a state of pleasant slumberland and render the operation entirely painless.

It is not a simple matter to prepare a big alligator for an operation, and when "Big Mose" had to be operated on for a large tumor on his foot, it was like handling a well-lubricated pig. In preparing Mose for the operating table his head was covered with a gunny-sack, then his jaws were muzzled, and he was securely fastened with strong ropes to a thick plank eighteen inches wide and twelve feet long. Local anesthetics rendered the removal of the tumor a painless procedure.

Some of the most difficult animals to control are the larger lions and tigers. A full-grown lioness, captured by the late "Buffalo" Jones, was noted upon her arrival to have some injury to her front feet. While she sulked and would not permit any examination, close observation detected the trouble to be that the claws had grown into the pads of her feet, making it necessary to destroy the nails. Getting this ferocious animal to an operating table was a real problem. However, the Lion House is very well equipped for all sorts of emergencies, and one of its modern improvements is an elevator with a fixed cage six feet long and two feet wide. Meat was placed in this cage, and the lioness was enticed into it. Once the lioness was trapped, a tarpaulin was placed over the cage, making it airtight. She was quickly chloroformed by means of an atomizer pump, roped and securely tied. The operation of removing the irritating claws was a matter of but a few minutes' work. The lioness' cage was then wheeled out of doors and she promptly came to. And what a racket she made! She roared and howled! The whole park resounded with her rage and anger. Visitors ran up, but one look was enough. The lioness plunged to the front of the cage, and though she had no chance to get loose, that crowd made for the exits without delay. The animal was well in about ten days and lived in the park for more than fifteen years, a good age for a lioness in captivity.

Bears also need plenty of surgical attention. Once one of our huge Alaska brown bears, while engaged in a fight, drove one of his canine teeth (two inches long) completely through his upper lip. The animal was wild with pain until he was chloroformed and the lip released by means of strong forceps.

It would make a charming commentary on our work if we could note any gratitude on the part of our patients for what we do for them. As a matter of fact, we rarely see any notable response of appreciation. I recall an orang-utan that was once treated for pneumonia and later became a thorough hospital addict. He was constantly looking for attention and was very agreeable about being treated for any ailment.

An unusual operation on animals, though it is not uncommon on humans, was performed on the eye of our Indian rhinoceros "Mogul." This rare animal, a splendid physical specimen, came to the Zoological Park with a cataract in each eye, causing blindness. It was necessary to perform the delicate needling operation in which a knife is inserted in the eyeball and the capsule of the lens is ruptured in order to dilute and permit the absorption of the opacity.

The operation is absolutely painless and is often performed on human patients without a general anesthetic, but with the rhinoceros it was necessary to place the animal under chloroform as well as to use cocaine on the eyeballs. The surgery was the easiest part. Preparing the patient for the operation was far harder. The animal weighed nearly two tons and had such big feet and short legs that it was a difficult matter to get him on the operating mattress. It required the united efforts of ten keepers to hobble and cast him. After two operations the animal was able to see.

DAY-DREAMS

By Dr. EDWIN G. FLEMMING

NEW YORK, N. Y.

No great work has ever been accomplished but that it had long before been achieved in the dreams of the doer. But in dreams there is danger as well as the seed of great deeds.

When desires are unsatisfied they are not eliminated from the sphere of influence in our lives. We continue to desire, we spend more or less of our time in wishing. And when there is even a lingering hope of securing our desires we continue to strive. The unsatisfied desire, kept alive by imagination and hope, then serves as the mainspring of effort.

But an interesting and important fact is that even when there is no hope of accomplishing our desires we still continue to dream about them. All of us have day-dreams in which we experience the possession of things that we do not possess, or in which we accomplish things to which we have not yet attained. We do not dream about things we have but about things we do not have. We do not dream about things which are easy to get but about things which we apparently can not get.

Ordinarily, when, through dreaming about things, we see a way which appears within our ability to achieve we are likely to attempt some kind of overt activity in order to secure our desires. But many people do not clearly see the means by which they can make their dreams come true. That is especially true of children; and if the child's day-dreaming habits are not wisely handled he may be unlucky enough to have the habit become fixed, so that through the rest of his life he is content with dreaming instead of attempting to do.

When the day-dream is serviceable to the individual we are inclined to say he has a good imagination or a very fertile mind. It is when imagining things appears to be an end in itself instead of a means to an end that we say the individual is a dreamer and visionary. The doer dreams just as much as the dreamer, but the doer is not content with his dreams.

Day-dreams first appear when something has gone wrong, when there is a discrepancy between desires and reality, when a person can not actually get what he wants, or when he gets what he does not want in the form of punishment. The child then wishes that things might be different, and wishing them different makes them different for the child mind. Day-dreams are then used as compensation for actual lacks in real life.

Such imaginings are pleasant to the child because he is the center of the dream in which everything happens as he "thinks" it ought to happen. Finding such imaginings pleasant the child begins to indulge in imaginative play, and may after a time find that such imaginative play is more satisfying than real play. For instance, a little boy—an only child—wanted a dog. The parents for one reason or another did not want a dog. The boy began to imagine that he had a dog. The particular, imaginary dog followed him home one day, a fact that he called to the attention of his grandmother as she was coming home from a shopping trip with him. The youngster dawdled along behind and had to be hurried every few minutes. Finally he said he couldn't hurry because his dog wouldn't mind. The grandmother indulged him and finally got him and the dog safely home after

a number of adventures. At home he took care of the dog as if it were a real dog.

There are other cases in which children create imaginary playmates who are the nicest children imaginable, always doing what their creator wants them to do. One little girl created during the course of a few years a whole world of people, a step at a time, in which she was the queen.[1]

The fact that the day-dream is used as a means of satisfying thwarted desires is of importance and it is likewise noteworthy that in the day-dream the dreamer occupies the central, exalted position. Where that does not happen in the beginning the dreamer very soon identifies himself with the central character of the dream. Such was the case in the development of the day-dream of the girl who had a whole world subservient to her wishes. At first she just had an imaginary playmate who could do the things the dreamer wanted done. When the playmates increased into a family, then a nation, and finally a world, the original imaginary playmate was their queen. But soon the dreamer identified herself with the imaginary queen and at last became queen herself.

Such dreaming is not in and of itself bad, but it is always indicative of some lack in the life of the youngster. If the lack continues and the child, through the development of the dreaming habit, comes to substitute dreaming for reality then there is danger. At first the dreamer recognizes that the dream does not represent reality, and the dreamer may pass from the dream state to reality at will. It is then that day-dreaming often takes the form of imaginative play. For instance, a little boy, who was removed from his usual environment in which he had several sisters with whom to play, found himself almost alone with only another boy about his own age as a playmate. The new playmate was stronger than he, and made him do things that frequently he did not want to do. The new playmate was boss, as it were, whereas with his sisters, who were all considerably older than himself, he was petted and catered to in everything. The child began to play having company. The visitors were always young ladies, who came to talk to him about parties and good things to eat. He talked to them about the things he had been doing or imagined he had been doing, sang for them, and treated them with imaginary ice cream and cake.

Playing house and school or playing storekeeper are of this same kind of imaginative play, in which the creator of the situation takes the dominating rôle and moves the creatures of his imagination about at will to do his bidding. Here the child identifies himself with the adults who, he has observed, have power to control the actions of others. Thus the child satisfies his repressed desire to be the central figure in his universe.

An interesting case of identifying oneself with the masterful is that of a boy, physically weak, who in his day-dreaming play became a general of whom he had read. He played with lead soldiers by the hour, moving them about and controlling them as he had never been able to control his playmates. He also had the habit of identifying himself with the characters about whom he read in fiction and history and added to the stories the things he wanted to happen. These dreams were so real to him that in school one day he put himself into a difficult position and maintained it with great vehemence against the prevailing opinion of the rest of the class.[2]

Not infrequently parents, whose own dreams and ambitions for themselves have remained unrealized and unrealiz-

[1] See George H. Green, "Psychanalysis in the Classroom," pp. 33 *ff*. G. P. Putnam's Sons, New York, 1922.

[2] See Caroline B. Zachary, "Personality Adjustments of School Children," Chapter I. Charles Scribner's Sons, New York, 1929.

able, dream dreams of accomplishment and success for their children. All too frequently such ambitions for one's children lead to difficulties for the children. When the dreams of the parents are unsuited to the talents and abilities of the child, the child is often forced and driven beyond his capacity, with the result that there is sure to be failure and the development of feelings of inferiority. Such day-dreaming parents do not check up their ambitions for their children with the facts of reality, and many a good merchant is spoiled to make an unsuccessful doctor or lawyer or preacher. Deans of men and women in colleges, teachers and principals of schools are all too familiar with the difficulties of the boy and girl whose parents are still day-dreaming and attempting to satisfy those dreams through the medium of the activities and accomplishments of children who would be better citizens, more successful in their careers and happier and more pleasant personalities if left to themselves to develop the talents and interests which they actually possess.

Day-dreaming and imaginative play of the day-dreaming type may in some cases go to such an extent that the individual tends to shut out reality and to take the dream for actuality. One boy had dreamed so much and often that he was a great inventor that he actually came to believe that he was a mechanical genius. As a child he was interested in all sorts of mechanical toys and devices. He dreamed that he was a great mechanical engineer. He "planned" all kinds of wonderful devices and became enormously wealthy as a result of his inventions. He explained his inventions to his father and to his uncle, who became convinced that the boy had unusual ability and would one day become a famous man. But he was never moved to work out any of his inventions on paper nor in the form of models. He was content with the dream.

He came to college heralded as an embryo mechanical genius. The professor of physics found very soon that he did not know the first thing about the elementary concepts of physics. And what was worse, he would not apply himself to learn them. Digging facts out of a physics text-book was hard work—much harder than dreaming great inventions. Some of the things he "invented" indicated an acute observation of mechanical needs. He talked over the problems with engineers and architects whenever he had a sympathetic audience, and it appears that some of his ideas showed a knowledge of general mechanical principles. But he had no knowledge of details, and less patience than knowledge.

One invention of which he had thought he was urged to work out in detail. He played around with the idea for a while and did make a crude drawing which, however, was of no service. He was then urged to make a model, which he promised to do immediately. But before he had started on the model he communicated with a patent attorney, or said he had, and said that the attorney pronounced the idea good. The attorney was going to make a search of the patent records to see if the idea was patentable. In the meantime he reported difficulties in getting materials for the model. He said he had written for them, but the house from which he had ordered the necessary items was slow in sending them. For almost a year he talked about his invention as if it were already an accomplished fact. He saw himself sought by Edison to be given a special training in order that Edison might have some one ready to take his place when he passed into the Beyond.

Later the boy transferred to another college where he thought he would be better understood and would have

greater opportunity to secure the training that would develop his great ability. After one term he left that institution and secured a position as an apprentice in a large manufacturing plant where he was sure the practical training would give him the opportunities that he could not find in an academic environment where the emphasis was too much upon the theoretical.

This boy had indulged so much in day-dreaming and had been unwisely encouraged to be satisfied with mere dreams instead of, at an earlier age, having been stimulated to translate dreams into realities that for some time to come he is bound to suffer from his inability to face things as they actually are. He will, in his own mind, be misunderstood by his fellows. If he has any real stamina, and through hard knocks, piled one upon another, is forced finally to look at the world and himself as it and he are, he may achieve something.

From shutting out reality it is only a short step to the process of abstraction in which the dreamer appears to be entirely oblivious to everything about him and wholly absorbed in his own thoughts. The absent-mindedness of the scholar is similar to the abstraction of the dreamer. The absent-minded professor, however, is more likely to be thinking about some troublesome problem in connection with a research project, or is working out a close argument for a lecture, or is mulling over some abstract concept of his particular specialty; he is not so likely to be imagining himself in an exalted position receiving the plaudits of the multitude or accepting honors from some scientific or philosophical society. To be sure, the absent-minded shut out reality and are abstracted; but the day-dreamer who is abstracted has gotten to that stage where, for the time being at least, it is as if the thing he is imagining is actually happening. One young man, for example, used to dream that he was speaking before audiences of thousands of people, holding them spellbound. While walking through the woods or alone along the open road he would deliver his oration as if before the packed amphitheater. His abstraction was such that he was at those sublime moments no longer himself but the great orator. When brought back to reality by some trifling incident he was conscious of the fact that he had been day-dreaming; but during the dream he was unmindful of everything and unconscious of the fact that the great occasion was not real. There was a slight tendency later to feel that the great orator was the real self.

If such abstraction should proceed further, as it does in pathological cases, one of two things may happen, depending upon other contributing factors. Either the individual becomes so convinced that he is the great Mogul and consequently incapacitated to carry on the normal activities of life that he is diagnosed as insane and sent to a hospital for the mentally ill; or he may develop an alternating personality. At one time he may be his normal self, with no knowledge of the other abstracted individual and his glorious experiences; and at another time he may be the individual he has dreamed of being, who likewise has no knowledge of the normal self. The realities of life may bring with them such emotional conflicts that the personality is split, the second personality living an existence that avoids the complications confronting the real personality.

A case in which the individual had gone to the ultimate extreme in identification and abstraction is that of an orphan girl who constantly imagined herself as a person in a very superior position. Just before she was committed to a hospital she sent for a reporter and told him a long story of her success in singing the leading part in Tosca. She explained to him that through some unfairness on the part of one of the opera

company she was forced to live in poverty.[3]

And so the mechanism of day-dreaming is invoked, all unconsciously, in order to bring the individual those satisfactions that are denied him in reality. Emotions and desires may be thwarted and repressed, but generally the organism finds some way of getting around the thwarting influences, often being satisfied with mere day-dreams.

In conclusion we would emphasize the fact that day-dreams are not necessarily a baneful influence in the efforts of the individual to adjust to the realities of life. They may in fact be the very basis for great achievement. The danger enters when one is satisfied with the shadow in the dream and makes no attempt to actualize the dream content. For parents and teachers and others who are concerned with assisting the young to make satisfactory and satisfying adjustments to the manifold problems of living, the caution should be registered not to attempt to eliminate day-dreaming, since such a procedure would only serve to drive the child further within himself. He would not cease to day-dream, but would merely refrain from telling about his day-dreams to the person who would repress them. The day-dream represents a real lack in the life of the dreamer. The proper procedure, consequently, is to inquire into the nature of the lack and to encourage the person actually to do something toward the realization of his dream.

CHANGING FAMILY SITUATIONS IN A SMALL COMMUNITY

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I

DURING 1931 a study of a small Middle Western community was completed. The study was unique in that the ethnographic technique was exclusively used. The major purposes were to accurately record the old culture which preceded the introduction of machines, and to record the reactions of the culture as a whole to the new situation brought about by the change in its material aspects.

In order to study the latter phenomena it was deemed advisable to choose a community which was comparatively free from the economic crises so dominant in industrial cities. The community chosen was one entirely dependent upon agriculture, but which was not isolated from urban culture. Other variables were likewise ruled out. The following brief description will suffice to make this clear.

Shellrock, Iowa, the community chosen, is in a rich agricultural area located about thirty miles from Waterloo, an industrial city of about sixty thousand inhabitants. It consists of a village center, which has averaged a population of 811 since 1885. During that time it has not varied more than fifty from that average. The country included in the community consists of a population of about 1,600. The entire wealth of the community comes from the surrounding farm land.

The town was founded in 1857, and by 1885 it had nearly reached its maximum size. It was founded largely by old American stock of the Protestant faith whose various sects are still em-

[3] See Caroline B. Zachary, "Personality Adjustments of School Children," pp. 54, 55. Charles Scribner's Sons, New York, 1929.

braced by the present citizens. Shellrock has never experienced an influx of foreign blood. In fact, only a very small percentage of new blood of any kind has come in since 1890. Moreover, both the commercial and agricultural groups have the same cultural and social origins. The two groups are not hostile to each other, but participate equally in the same social activities. Such a community can not in any way be called typical, and no such claim is made.

A third purpose was to initiate a social study which would approach the nature of a controlled experiment. Unlike the chemist, the social scientist is not able to set up an experiment but must content himself with describing the social phenomena resulting from existing combinations of variables. If the social scientist, however, studies one group and clearly defines the variables, he may later follow up with the study of another situation which may differ in only one variable from the first. For instance, the above items have been noted in the Shellrock complex. Now if we follow this study by one of another community which is similar to the first except, let us say, in racial composition, it should be possible to note crudely the influence of the racial factor in combination with a specific complex. This method, although less accurate, would approach that of the controlled experiment in the physical sciences.

II

The newspaper files, as well as any other available written material, were read, but they were one of the minor sources of information. The most information, especially that concerning the fundamental attitudes, standards and evaluations of the people, was obtained from the old residents who are still living. Direct questioning of informants brought questionable results. The best information was gained through listening to the group conversations of the people, and participating with them in their group activities.

The questioning method was completely abandoned. Although the questionnaire easily lends itself to quantitative study, it is likely to reveal rationalizations rather than actual fundamental attitudes. Participation and observation results in more accurate information.

After the complete record of the community activities was concluded, an analysis of the family situations was made. A portion of that analysis follows.

The most outstanding thing was the interrelationship between the family organization and the other social phenomena. One large section of the study was devoted to the family. In that chapter was a great mass of material on economic and other social life. Likewise, all the other chapters contained important material on the family situations. It would have been impossible to accurately record or understand the family situations if they were isolated from the entire social and economic complex. This close relationship will be still more emphasized by the points which follow.

Life in the country, with the existing economic and social traditions, demands the united efforts of a man and woman. Agriculture represents one of the most primitive industries of man, and, consequently, retains more of the primitive traits of social organization than the more recently evolved industries of manufacturing, found in the urban areas. No provisions, for example, were made in the organization of agriculture to accommodate the single man or woman. The tradition of certain work for men, as distinguished from other work for women, is still strong in the rural areas. The family is the economic unit of farming.

Women's work is largely limited to the care of the house and the minor indus-

tries of the farm. Among the latter is included the care of the garden. In Shellrock, the division of labor incident to plant culture corresponds with the world-wide pattern of woman as the horticulturalist, while man appears in the rôle of agriculturalist.

In the case of the dominant woman who can make her husband take part in the gardening, the latter usually plants the seeds in the corn rows, and, rather than hoe it, he plows it with the corn cultivator.

With regard to the division of income, the general rule of the community is that the income from all major activities of the farm belongs to the man, while the income from minor activities conducted by the wife belongs to her. This is well illustrated by poultry raising. Under the old system the woman cared for the chickens and received the money acquired from the sale of eggs and surplus roosters. With this money she financed the household. Since the introduction of the coal or oil hover type brooder, and custom hatching, chicken raising has become less tedious and uncertain and the financial returns greatly increased. With this change in the financial importance of poultry raising the men have taken it over and the income no longer belongs to the women.

Other changes in material culture have reduced woman's work. Formerly, all the bread, as well as cake, cookies, pie and other pastries used by the family, was baked by the housewife. A large portion of the vegetables and meat were canned, dried or cured by the wife for use during the winters. The family used to be practically self-sufficient. As late as 1912 the worst thing that could be said regarding the shiftlessness of a family was, "They live out of a tin can and paper sack." It was only the lower classes who lived in that way, but now the trait has percolated upward to all classes.

This increased dependence upon the outside world has raised the cost of living. The increased cost of the necessities, plus the increased number of luxuries desired as the result of advertising, has resulted in a decrease in the number of children per family. In three generations the average number of children has dropped from six to two per family. From talks with men in the harvest fields and conferences with women one is given the impression, and often told openly, that children are accidents. Four children are considered an indecently large number, and usually only ne'er-do-wells have such large families. Birth control is taken as a matter of fact and is not even considered a debatable matter.

When asked why they do not have more children they plead economic pressure. This economic pressure, however, results from the desire for luxuries, such as automatic refrigerators, automobiles and electric light-plants. Not infrequently one hears a woman remark as she looks enviously at a new automatic refrigerator, "We were going to get one, but now that we had the baby we must give it up, one has to give up so much for their children."

Children, moreover, are a greater social liability now than formerly. Since the shift away from home-made recreation there is no place for the small child or pregnant woman. Pregnancy is discussed as if it were a disease, and the pregnant woman is "pitied" by her friends. Often one hears such remarks as "Poor Mary, she feels so badly about having another baby."

The child no longer has an important place in the family. With the increased importance of education his contribution to the economic process has been reduced to a minimum, while his needs have become a greater strain upon the family finances.

The shift to commercialized entertainment has made recreation become an individual rather than a family activity.

This not only weakens the family, but is a source of internal friction. While the family was the unit of entertainment the control of the young group was comparatively simple, for they were under the surveillance of the elders. The automobile and the individualization of recreation take the young people out of the range of adult supervision.

The automobile has become an indispensable tool of courtship. As yet the family is not organized to meet the problem presented, and a great deal of conflict results. Each boy is certain that his family, out of sheer perversity, will not permit him the use of the car, and his parents are equally sure that "he doesn't care if we get to go anywhere or not." Both sincerely believe the other to be selfish. The boys seldom get the machine until after much coaxing and many temper tantrums on both sides. Because the boy never knows when he will get the car the "dates" are made "on the spot" rather than in advance.

Neither the parents nor children know how to cope with the problem. The elders look to the past as their guide, while the children face the immediate problem and get their way through any tactics. The most pitiful conversations overheard are those in which a group of parents stimulate each other with tales of how thoroughly they uphold the established group sanctions in their families. For a few moments, away from the actual dilemma, they play the part of bold champions of the old order. A check, however, shows that they are only play acting.

Another force operating to weaken the family is the lack of economic opportunity for the young people within the community. This lack of opportunity causes the youth to look toward the outer world. The community attitudes reflect the recognition of this scarcity. The parents expect their children to leave home upon graduation from high school. The community as a whole expects them to leave. In the opinion of the community going to the city is a step toward success. To remain at home after graduation is considered an indication of lack of worth. The boy who remains in Shellrock and takes over his father's business and runs it successfully does not enjoy the prestige of his classmate who leaves town and is fairly successful in the city.

III

In conclusion we may say that the ethnographic study of Shellrock gave four important results.

First: The family situation can not be studied alone but must be analyzed in its cultural matrix.

Second: Primitive characteristics of organization are retained until new material traits are introduced. Then there is a breakdown of the organization and an aimless groping after another form.

Third: The introduction of our new material culture has weakened group organizations, and, temporarily at least, strengthened individualism.

Fourth: The family ties are being severely strained by the new material culture and the social results incident thereto.

ACTION OF A RUNNING HORSE

By Dr. EDWIN H. HALL

EMERITUS PROFESSOR OF PHYSICS, HARVARD UNIVERSITY

IN the SCIENTIFIC MONTHLY for December, 1931, I spoke of a drawing made by Clerk-Maxwell as a boy of eleven years, reproduced here as Fig. 1, saying that it showed an astonishing perception of a horse's action in running, and I contrasted this drawing with the conventional representation of running horses in the sporting prints of Maxwell's boyhood. Two such representations are shown in Figs. 2[1] and 3. It will be noted that every horse shown in these two pictures, which are fairly typical of the ordinary prints of their time, has his forelegs reaching far forward and his hind legs reaching far backward, in a rocking-horse attitude. Instantaneous photographs, which of course were unknown when these prints were made, rarely if ever show a running horse in this position. The fact probably is that the unaided eye of the ordinary spectator notes each pair of legs in its most extended position, because that is the simplest position and perhaps the one of least rapid change of aspect. It fails to note that the extension of the forelegs is not, as a rule, simultaneous with the extension of the hind legs. Every horse shown in Fig. 3 seems in danger of dragging his hind feet on the ground at the next instant and incurring some rupture of his anatomy in consequence.

[1] Figs. 2, 3 and 4 are taken from Nevill's "Old English Sporting Books."

FIG. 1. A SKETCH MADE BY MAXWELL WHEN HE WAS ELEVEN YEARS OLD

FIG. 2. ILLUSTRATION FROM "ANNALS OF SPORTING" VOL. III, 1823
ENGRAVED BY THOMAS SUTHERLAND AFTER SAMUEL ALKEN.
(By courtesy of Messrs. T. Rimell & Son.)

Muybridge's instantaneous photographs[2] of a running horse show a decidedly complicated action of the legs. It appears that the horse studied, after his flight with all four feet off the ground, lands first with one hind foot (say the left), then with the right hind foot, then with the left forefoot, then with the right forefoot. Muybridge calls this gait a "cross gallop." Some animals after the flight land with a different one-two-three-four order of the feet. Cats and racing dogs land on the forefeet, then bring the hind feet far forward and leap almost wholly with the hind legs.

A leaping horse, in clearing an obstacle, takes off and lands very much as a cat or a racing dog does in plain swift running. The early part of a horse's leaping flight is well shown in Fig. 4, evidently not a photograph. Clerk-Maxwell's sketch, Fig. 1, shows a somewhat later stage of the leaping flight, rather than an aspect of the plain run, if Muybridge's photographs show the only type of action in such a run. How veracious Fig. 1 is, for a leaping flight at least, can be seen by comparing it joint by joint with Fig. 5, an instantaneous photograph of a horse in flight over a hedge.

A great many years ago I read a thrilling short story of a cross-country race, in Ireland, between an American horse named Choolook, carrying an American rider, and an English horse named Inkerman, carrying an Englishman, the prize being, of course, the hand of an Irish lady. The writer of the story, who seemed to know all about horses, spoke well of Inkerman. Inkerman was a good horse under a gallant rider. "Inkerman could run," but Choolook could and did "run like a cat," landing from his flight on his forefeet; and, said the author, the horse that runs in this way need never fear the

[2] "Animal Locomotion," Vol. 9, to be looked for in the Fine Arts Department of large public libraries. Published in 1887 under the auspices of the University of Pennsylvania. See also Muybridge's "Animals in Locomotion," London, Chapman and Hall, 1899.

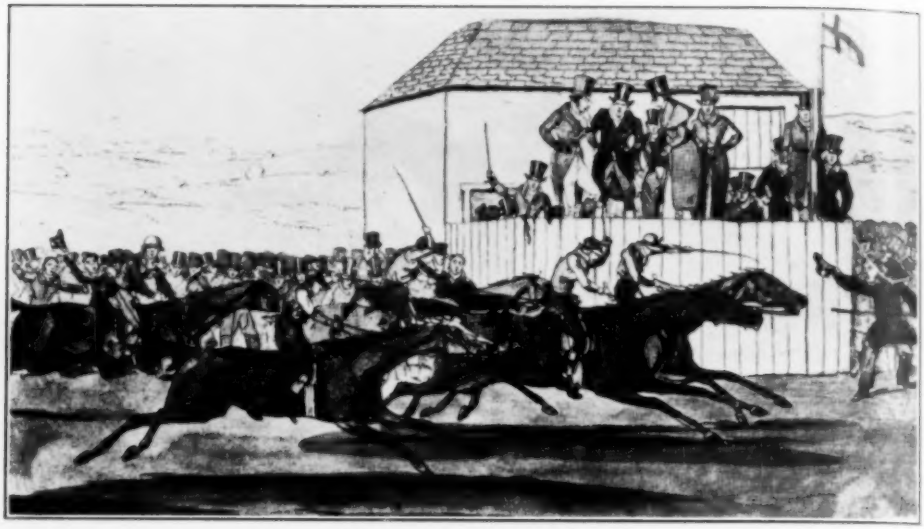


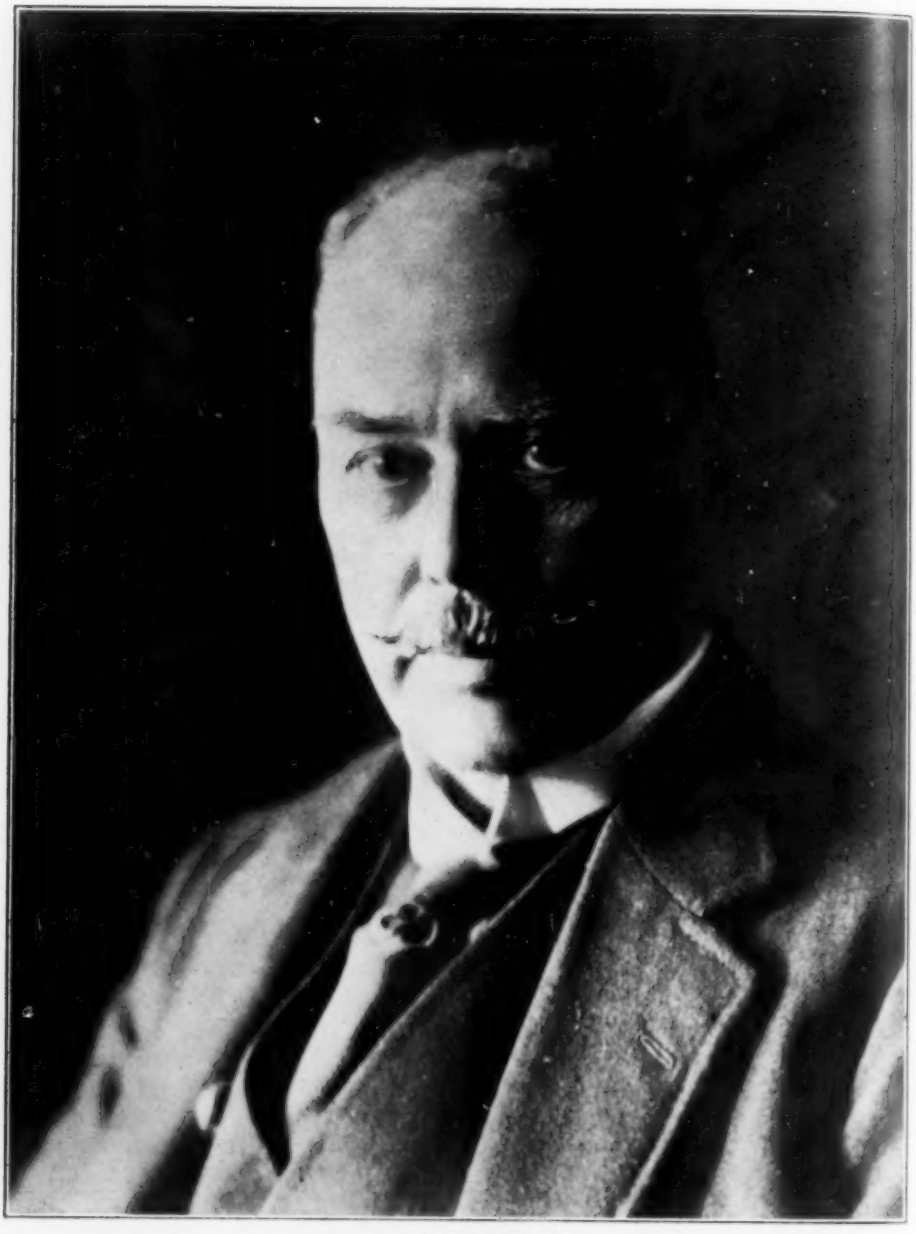
FIG. 3. ASCOT RACES

FIG. 4. ILLUSTRATION BY W. T. MAUD

FROM "HAWBUCH GRANGE" BY THE AUTHOR OF "HANDLEY CROSS," ETC. 1847 EDITION.
(By courtesy of G. de A. Lopes, Esq.)

FIG. 5. UP AND OVER

horse that does not. So for nearly sixty years I have supposed that I knew the gait of the super running horse to be the same as the gait of a running cat; but a recent study of Muybridge's photographs leaves me wondering. Was my convincing story-writer wrong or did Muybridge generalize from the photographic study of too few horses? Is Man-o'-War or Gallant Fox, for example, an instance of the horse that runs like a cat, or is there no such animal?



SIR RONALD ROSS

WITH HIS DEATH ON SEPTEMBER 16 AT THE AGE OF SEVENTY-FIVE YEARS, THE WORLD HAS LOST ONE OF THE GREAT KNIGHTS OF MODERN SCIENCE. HIS WORK ON THE CAUSE AND CONTROL OF MALARIA WON FOR HIM THE NOBEL PRIZE IN 1902.

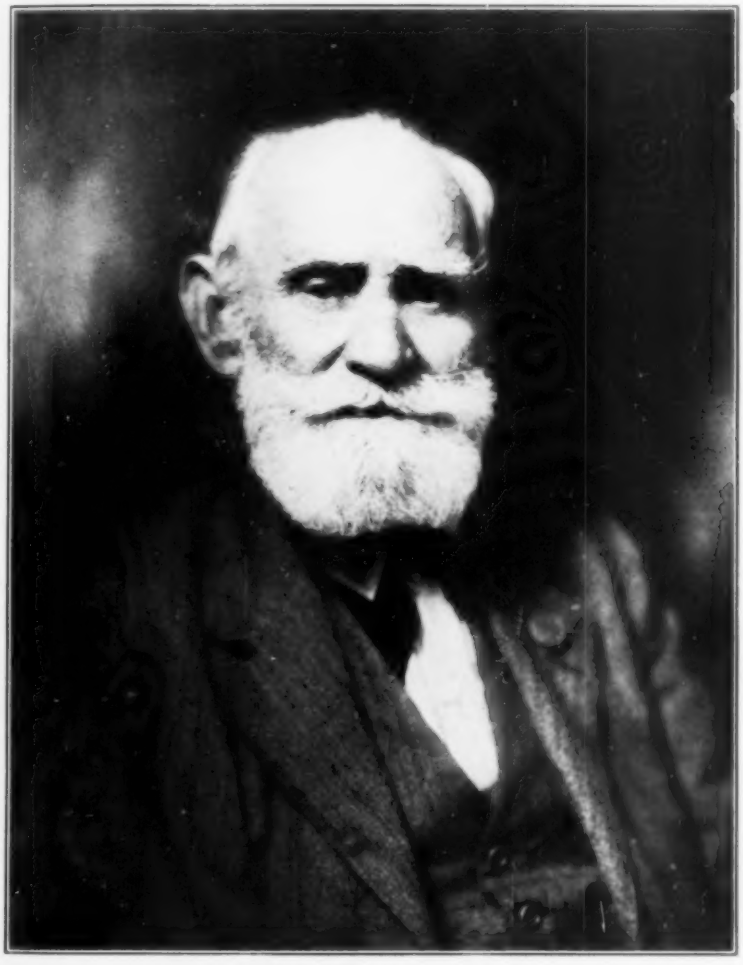
THE PROGRESS OF SCIENCE

THE INTERNATIONAL CONGRESSES OF PHYSIOLOGY AND PSYCHOLOGY

THREE years ago the International Congresses of Physiology and Psychology met in the United States—the physiologists at Harvard University and the psychologists at Yale University. Now the congresses have again met, this time widely apart—the physiologists at Rome and the psychologists at Copenhagen.

The Quirinal and the Vatican united to make welcome the Fourteenth International Congress of Physiology, which met at the beginning of September. Premier Mussolini presided over the opening session; and the members of the Congress were later received in audience by Pope Pius XI.

The Congress was held under the presidency of Professor Filippo Bot-



PROFESSOR IVAN P. PAVLOV

AT THE MEETING OF THE FOURTEENTH INTERNATIONAL CONGRESS OF PHYSIOLOGY IN ROME, PROFESSOR PAVLOV WAS ELECTED TO THE PRESIDENCY OF THE CONGRESS WHICH WILL MEET IN RUSSIA IN 1935.

PROFESSOR FILIPPO BOTTAZZI
OF THE UNIVERSITY OF NAPLES, UNDER WHOSE PRESIDENCY THE INTERNATIONAL CONGRESS OF PHYSIOLOGY WAS HELD.

tazzi, of the University of Naples. The principal address was given by Professor A. V. Hill, of University College, London, who spoke on the physiology of muscular action. Another address of outstanding interest was given by Professor Ivan P. Pavlov, who celebrated his eighty-third birthday on September 26. He had also the week before addressed the psychologists at Copenhagen. Among the papers read in the sectional meetings was a series on the chemistry of muscular contraction.

The United States was well represented at the Congress, with a delegation of about one hundred, including Dr. W. H. Howell, president of the preceding Congress. The next International Congress of Physiology will be held in Russia in the summer of 1935, under the presidency of Professor Pavlov.

The psychologists decided to meet in Copenhagen largely to do honor to Professor Harald Höffding, one of the leaders in the foundation of modern psychology, who, however, died at the age

HARALD HÖFFDING

WHOSE DEATH PREVENTED HIM FROM FILLING THE OFFICE OF PRESIDENT OF THE TENTH INTERNATIONAL CONGRESS OF PSYCHOLOGY.

of eighty-eight years before the time of the meeting. Professor Edgar Rubin, of the University of Copenhagen, was chosen to succeed him.

The King of Denmark presided at the opening exercises, and there were numerous receptions and entertainments, such as can be provided to special advantage at Copenhagen or Stockholm—perhaps the two most civilized cities in the world. One of the receptions was held in the beautiful house and park given to the Danish Academy of Sciences as a residence for one of its distinguished members. It had been occupied by Professor Höffding and is now assigned to Professor Niels Bohr.

The scientific program included 157 papers, and there were about 500 members in attendance, 98 of these from America, including Dr. J. McKeen Cattell, president of the preceding Congress; Dr. C. E. Seashore, chairman of the delegation appointed by the United States Government, and Dr. W. R. Miles, president of the American Psychological Association. The next Congress is to be held four years hence in Madrid under the presidency of Professor L. Myra, of the University of Barcelona.

THE ITHACA MEETING OF THE AMERICAN PSYCHOLOGICAL ASSOCIATION

BINARY fission is recommended as a possible remedy for the ills of the body of psychology, at present pulled two ways between the introspectionists of the classical school and the modern disciples of the experimental method. Dr. Robert M. Yerkes, of Yale University, made this suggestion of an amicable bill of self-divorcement before the meeting of the American Psychological Association at Ithaca. He would classify the two sub-disciplines of the science of psychology respectively as psychology and psychobiology.

Children learn the "right" colors for a picture at a very early age, it was indicated by experiments reported by Dr. Ada Hart Arlitt and Pessa Polasky, of the Pre-School Laboratory of the University of Cincinnati. They showed their young subjects twenty masterpieces of art, first in their original colors and then colored in violation of the laws of color harmony. Increasing numbers of the children preferred the original masterpieces. The children, however, showed no choice between primitive pictures and examples of modern art dealing with the same subjects.

When a baby and an infant ape of the same age are brought up together, the more rapidly maturing simian at first outstrips its human companion in learning manipulative processes, Dr. W. N. Kellogg, of Indiana University, stated. The superiority of the ape was probably due in large measure to its strictly human environment, he believes.

A similar experiment performed by Dr. Louis W. Gellermann, of Yale University, however, brought out evidence that even at an early age the young human can outreason the young ape. In coordination tests with geometrical figures, with food as a reward, two babies learned the right marks more quickly than did two young chimpanzees. The chatter of the babies as they puzzled over the boxes showed that they learn not alone by trial and error but by thinking out the problem in words. This superior ability to verbalize distinguishes the mentality of human beings from that of apes, Dr. Gellermann believes.

Contrary to the glib and hasty popular generalization that "at sixteen you are as intelligent as you are ever going to be," Dr. Louis D. Hartson, of Oberlin College, found that upper classmen in college surpass entering freshmen in the performance of standard psychological tests. In only one subject, arithmetic, did the younger student excel. As might have been expected, students about to graduate made the highest scores in the general subjects in which they had "majored."

Ten-point type with two-point leading, such as is used in the SCIENTIFIC MONTHLY, is most readable, tests reported by Dr. Miles A. Tinker, of the University of Minnesota, indicate. Any of the "orthodox" type faces make for easy reading, but "freak" types slow the reader down and let his attention wander. The ideal length for a line printed in ten-point type, Dr. Tinker said, is three and one third inches. Type with only a single lead between the lines is no better than type set solid.

Parents and mental hygienists differ regarding what constitutes bad behavior in a child, Dr. Ralph M. Stogdill, of Ohio State University, discovered by questioning a considerable number of both classes. Parents in general regarded as reprehensible conduct that contravenes conventional standards, such as disobedience and violation of social taboos. Hygienists were more concerned over things that operate to the disadvantage of the individual himself, such as bashfulness and day-dreaming.

Performance taught under the stimulus of rewards is learned at a rate in proportion to the promptness with which the reward is given, Dr. John B. Wolfe,

of the University of Illinois, learned in experiments with albino rats. Delays of 5 and 30 seconds, and of 1, 2½, 5, 10 and 20 minutes were used with trials of no delay for comparative purposes.

Most animals used in psychobiological tests learn their way through a maze most rapidly when a reward of food awaits them. Not so with ants, however; they learn the maze most rapidly when they are on their way back home with a prize they have found. Tests with these unusual subjects were reported by Dr. T. C. Schneirla, of New York University.

Electric currents, even though they have the same form and frequency as sound waves, do not serve in the same way as a stimulus to the auditory nerve, Dr. George Kreezer reported. The relation between the electric currents which accompany the nervous impulse from the ear to the brain and the sound waves which produce the stimulus have long been under investigation. The auditory currents, it has been stated, have the same form and frequency as the sound waves. In Dr. Kreezer's experiment, cats were conditioned to expect food when they heard a certain sound. Then an electric current of the same form and frequency was applied to the auditory nerve. Contrary to the expectations of the experimenter, the animal did not respond.

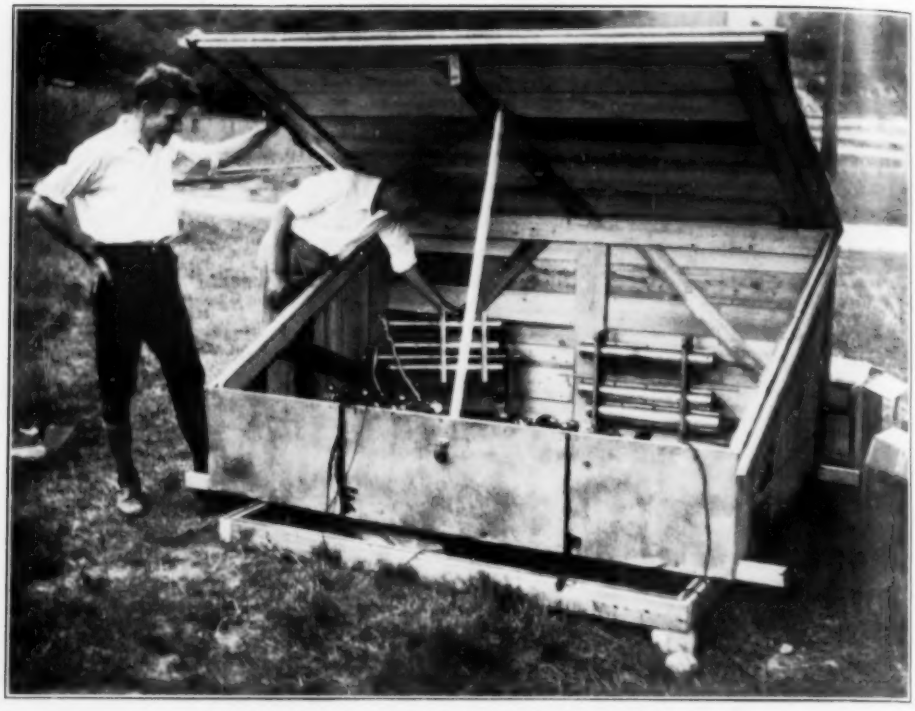
That superior intelligence is an inheritable trait was indicated by experiments reported by Dr. R. C. Tryon, of the University of California. He has propagated two inbred strains of rats, one more intelligent than the average, the other less intelligent. Animals of the superior strain maintain their superiority throughout most of their life span, and are succeeded by superior progeny. In this experiment, environmental factors were kept under control as completely as possible. The inheritance of physical factors such as weight, sex, pigmentation and fertility seemed to have no relation to the inheritance of mental ability.

COSMIC RAYS AT FORTY BILLION VOLTS

A NEW estimate of the energy of cosmic radiation, by Dr. Thomas H. Johnson, of the Bartol Research Foundation of the Franklin Institute, sets its voltage forty times higher than the highest guess previously made, and far beyond the possibility of synthetic duplication by any apparatus at present constructed or even imagined. If this estimate proves to be of the correct order of magnitude, physicists must perforce be contented with studies of the radiations as they naturally occur, for their production under controlled laboratory conditions will be out of the question for a long time to come.

The clue on which Dr. Johnson worked was furnished by photographs made at the California Institute of Technology by Dr. Carl D. Anderson. These indicated that at least some of the radiations commonly measured are secondary, arising from the collision of cosmic rays with particles of earthly origin. Calculations based on this fact indicate an energy content of the primary cosmic rays at the earth's surface of about twenty billion volts. Dr. Johnson estimates their energy at the outer limits of the atmosphere to be about double this, or forty billion volts. This is a figure forty times higher than the present estimates, and four hundred times higher than Millikan's original modest estimate of ten million volts.

The still mysterious source of cosmic rays, conjectured by Millikan to arise in the formation of new elements in outer space, is sought in a new place by one of his colleagues at the California Institute of Technology, Dr. R. M. Langer. Dr. Langer sees them as a possible by-product of the combination of positive and negative magnetic poles, set up by Dirac as the beginning-points of atomic construction with the positive electron,



DIRECTION FINDER FOR COSMIC RADIATION

DR. T. H. JOHNSON AND DR. J. C. STREET, OF THE BARTOL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE, WITH APPARATUS USED ON MT. WASHINGTON TO SEEK FOR POSSIBLE DIRECTIONAL EFFECTS IN COSMIC RADIATION.

newly suggested also by Dr. Anderson's photographs. The energy given off by such a combination would be of the same order as that of cosmic radiations.

In the meantime, field observations of these radiations continue with increasing exactness. Dr. Millikan has had recording electroscopes carried in airplanes to altitudes of over 20,000 feet in northern Manitoba and elsewhere. He has also repeated his observations at Arrowhead Lake, in California, using the same recording electroscope instead of the original visual observations.

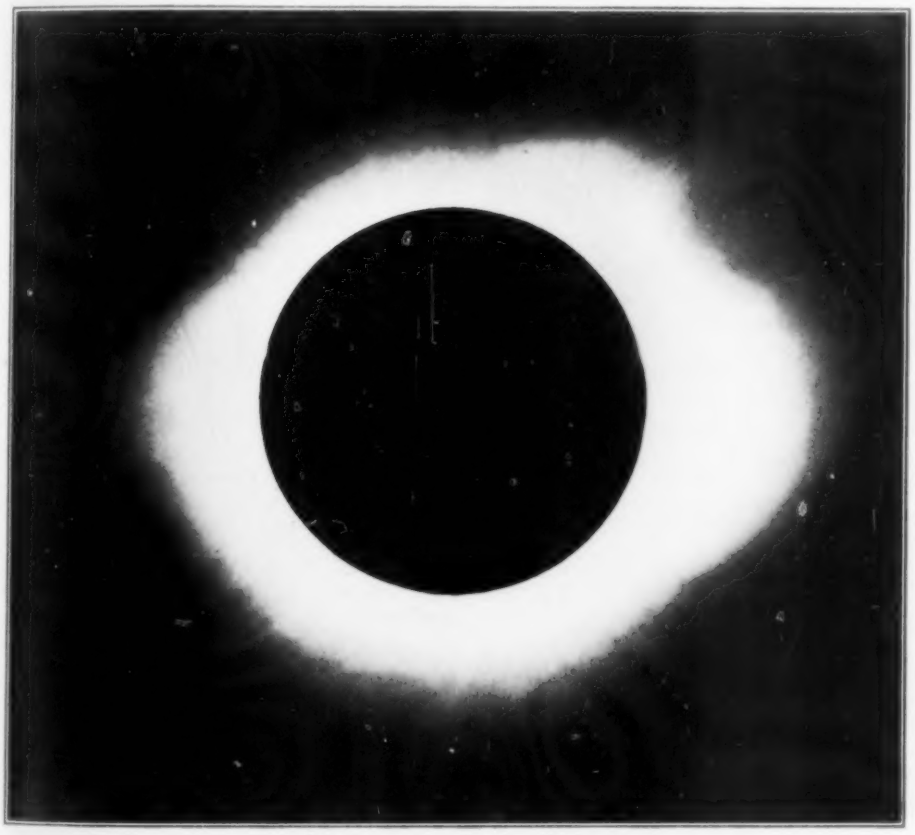
The possibility of a partial north-and-south orientation of the cosmic ray incidence is indicated by results of observations on Mt. Washington, New Hampshire, by Dr. T. H. Johnson and Dr. J. C. Street, of the Bartol Research Foundation. They used a "telescope" in which three Geiger-Muller counters were connected in series, so that the same ray had to pass through all three in order to be counted at all. Their directional results, though not large, are sufficiently within the limits of probable error to indicate that the effect is real. This work lends support to similar conclusions reached by Dr. A. H. Compton, of the University of Chicago, who has been making observations through a wide range of longitude during recent months.

Penetrating radiations resembling the cosmic rays, though of a much lower order of intensity, seem to be released during lightning flashes, Drs. B. F. J. Schonland and J. P. T. Viljoen, of the University of Capetown, state, in a communication to *Nature*. They used a Geiger-Muller counter while distant thunder storms were in progress, and obtained a high rate of coincidence in the instrument's "kicks."

PRELIMINARY RESULTS FROM THE TOTAL ECLIPSE

ALTHOUGH it is of course as yet too early to expect full astronomical results from the many expeditions that set up their cameras and other apparatus in the eclipse path through Canada and New England last August 31, nevertheless there are a few preliminary results worth brief mention. Astrophysical and meteorological observers were on the watch as well as astronomers, and their data first became available.

One of the most keenly watched phenomena during and immediately after the eclipse was the behavior of the Kennelly-Heaviside layer, for it was a moot point between American and British radio engineers whether this ionized reflecting layer in the upper atmosphere is caused by solar radiation or by a bombardment with corpuscles shot out from the sun with a velocity much less than that of light. Observations by physicists of the U. S. Bureau of Standards and by Canadian physicists agreed in supporting the American contention that radiation, presumably ultraviolet, is responsible. The "corpuscular eclipse" failed to materialize. The critical frequency of the E or lower region of the Kennelly-Heaviside layer decreased approximately a thousand kilocycles during the eclipse, lagging



THE TOTAL SOLAR ECLIPSE

PHOTOGRAPH MADE BY THE UNIVERSITY OF MICHIGAN ECLIPSE EXPEDITION AT FRYEBURG, MAINE, ON AUGUST 31. A FORTY-FOOT CAMERA WAS USED WITH AN EXPOSURE OF 34 SECONDS.

NEW HEAD OF INTERNATIONAL ASTRONOMICAL UNION

DR. FRANK SCHLESINGER, DIRECTOR OF THE YALE OBSERVATORY, WHO WAS CHOSEN PRESIDENT OF THE UNION AT ITS MEETING HELD AT HARVARD UNIVERSITY AFTER THE SOLAR ECLIPSE. THE NEXT SESSION OF THE UNION WILL BE HELD IN PARIS IN 1935.

behind its phases by approximately five minutes. After return to normal no later effects were observed.

Dr. Charles F. Brooks, of the Blue Hill Observatory, Massachusetts, watched for wind and other meteorological effects along the eclipse path, being aided by volunteer observers at many points who sent up pilot balloons, while Dr. Irving Langmuir, of the General Electric Company, ascended to a height of 9,000 feet in an airplane. A definite change in wind direction, from south to east, blowing from the eclipse path, was observed.

Astronomers met with varying fortune. Cloudiness was heaviest inland and least on the Maine coast, so that in general results were poorest in Quebec and best in the Portland neighborhood. The Harvard University and Japanese expeditions had the most nearly perfect conditions, and took full advantage of them. The reports that the Japanese observers had detected a new element in the sun, widely circulated by the press the day after the eclipse, were categorically denied by them. The corona, as observed and photographed by several expeditions, was of the sunspot-minimum type.

Anticipating the unsatisfactory weather conditions, several observers had arranged to get above the clouds in airplanes, and for the first time in eclipse-observing history an autogiro was used for this purpose. On the ground, two parties, one headed by Professor John Q. Stewart, of Princeton University, the other by Dom Maurus Moorat, of Ramsgate Abbey, England, raced the cloud shadows in automobiles, both finally succeeding in finding favorable locations to set up their portable equipment and make visual observations.

EARTHQUAKE AND HURRICANE

THOSE twin angels of destruction, earthquake and hurricane, have been more than ordinarily active during recent weeks. There have been several severe shocks, but fortunately only one of them affected a thickly populated region.

That one, however, made up in its destructiveness for the lack of disaster to follow the others. On Monday, September 26, a quake of most unusual violence shook the Greek coast in the region of the peninsula of Khalkidike, causing considerable loss of life, great destruction of property, and some damage to the historic monastic buildings in

HOMES WRECKED BY THE EARTHQUAKE IN GREECE

DAMAGE WROUGHT BY THE HURRICANE IN PUERTO RICO

the famous Mount Athos region. To the loss of life occasioned by the earthquake itself must be added many drownings, when the small island of Amogiana, to which refugees from the mainland had fled, was flooded—some accounts stating that it had sunk beneath the sea. Strong after-shocks continued to be felt for more than a week following the main disaster. The epicenter of this earthquake was under the sea a little distance off the coast of Khalkidike; this point was determined by the U. S. Coast and Geodetic Survey and the Jesuit Seismological Association, under their cooperative arrangement with *Science Service* as the clearing-house for telegraphic transmission of earthquake data obtained by seismological observatories.

Three days before the Greek disaster, an earthquake centering in southeastern Siberia was located by the same agencies. Since this is a region well off the main lines of communication, direct news of this earthquake may be some time in reaching the outside world. On previous occasions, earthquakes traced to interior Asia by calculation from instrumental data have been reported by courier weeks later.

On October 1 an earthquake of moderate intensity shook the city of Managua, in Nicaragua, the victim of a major earthquake disaster on March 31, 1931. This quake was traced to an epicenter at sea a short distance off the Pacific coast of Nicaragua.

The destructiveness of the Old World earthquake was more than matched by that of a New World hurricane, which raged through the West Indies during the last days of September, wreaking especial havoc in Puerto Rico, which has been staggering slowly to its feet after a similar misfortune four years ago.

The Puerto Rican storm was the fifth of the present season. According to the U. S. Weather Bureau, three such disturbances can be expected in a normal year. One of the previous storms was also unusually severe. It appeared to be headed straight for southern Florida, but when it was only two hundred miles off shore it veered sharply from its course and spent its force over the Atlantic Ocean.

THE PHYSIOLOGY OF RESPIRATION

Professor Otto Warburg, working with Dr. Walter Christian at the Kaiser-Wilhelm Institut für Biologie at Berlin, has discovered a second respiration ferment, distinct from haemin, the earlier discovery of which won for him the Nobel Prize in medicine and physiology in 1931.

Professor Warburg and Dr. Christian found that anaerobic organisms shaken up with oxygen underwent a respiration which could not be stopped by carbon monoxide or hydrocyanic acid, poisons which inhibit the action of haemin. They also found the same action to take place with expressed juices from ordinary aerobic cells. This appeared to indicate the existence of a respiration ferment other than haemin.

They have succeeded in isolating this ferment. It is present in high concentrations in anaerobic cells. It is an orange-colored substance that breaks down when heated for ten minutes at 60 degrees Centigrade.

A hitherto unnoticed respiration phenomenon has been observed at the Westinghouse Research Laboratories at East Pittsburgh, Pennsylvania, by V. Everett Kinsey. He placed pieces of normal and of cancerous human tissues in specially constructed glass respiration chambers, and exposed them to x-rays. Upon analysis of the gases in the chambers after the treatment, he found hydrogen, which is not normally an end-product of respiration. He is of the opinion that the disturbance of metabolism which causes this abnormal loss of free hydrogen is the cause of death of both normal and cancerous tissues subjected to prolonged x-ray exposure.